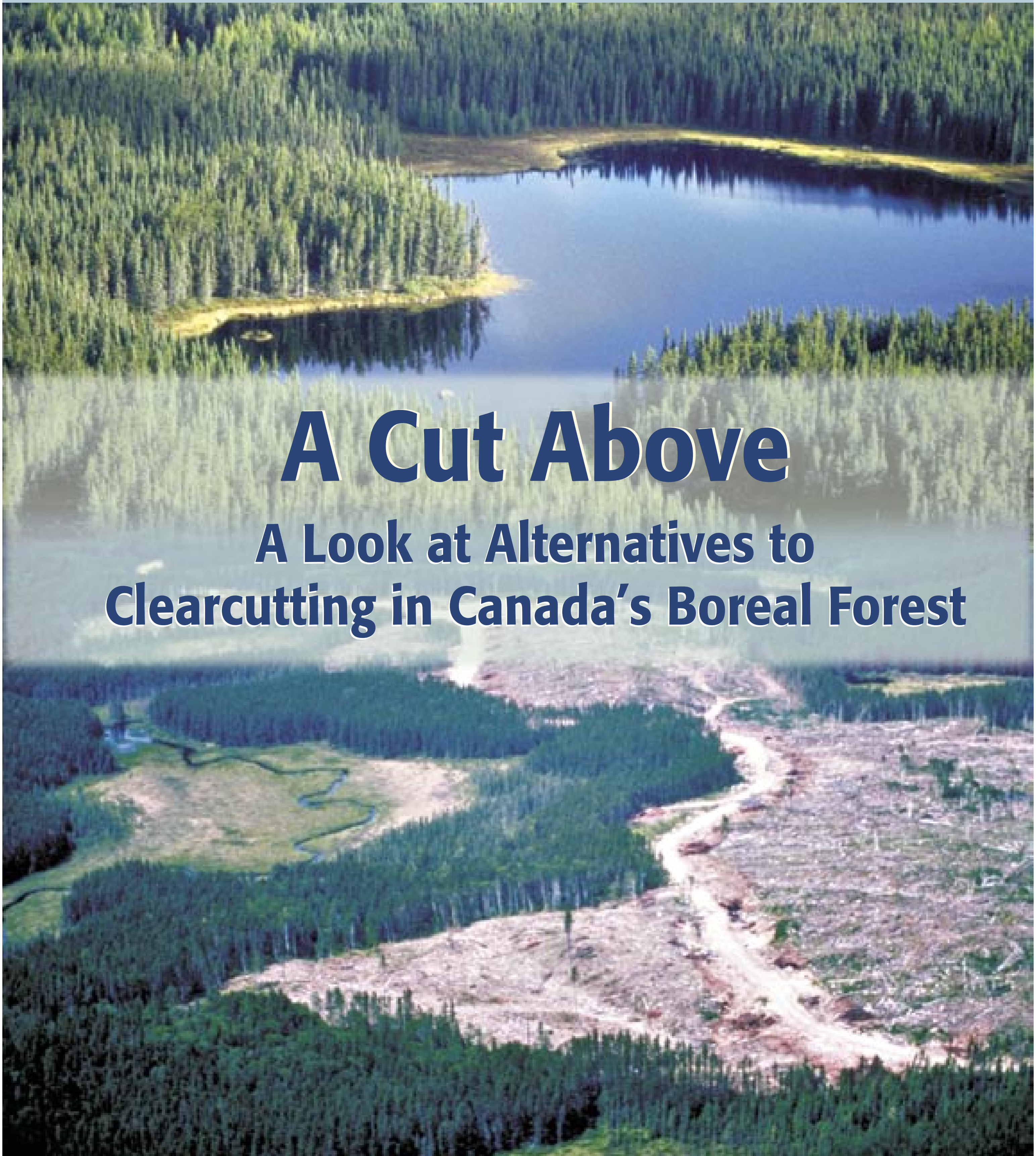
A Cut Above

A Look at Alternatives to Clearcutting in Canada's Boreal Forest



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A Look at Alternatives to Clearcutting in the Boreal Forest

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WILDLANDS LEAGUE

A chapter of the Canadian Parks and Wilderness Society

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About the Wildlands League

The Wildlands League's mission is to protect wilderness through the establishment of protected areas and through the promotion of natural resource use that is sustainable for nature, communities and the economy.

The Wildlands League was founded in 1968 to protect wilderness in Ontario. We joined the Canadian Parks and Wilderness Society (CPAWS) as a chapter in 1980. We are solutions oriented and we get results. We are respected for our science-based campaigns to establish new protected areas, our efforts to ensure that nature comes first in the management of protected areas, and success at addressing issues of resource management and community development.

Wildlands League is a charitable non-profit organization and is affiliated with 11 other CPAWS chapters across Canada.

Wildlands League works in partnerships with other conservation organizations, government, individuals, communities, First Nations and business. Specifically, we seek innovative ways to develop new solutions and achieve results that can be used to solve broad conservation challenges.

Some of our most important accomplishments include: key participation in the establishment of 2.8 million hectares of new protected areas through the 1997-1999 Lands for Life land-use planning process; establishment of a park planning system for Ontario; protection of over 160,000 hectares of wild areas in Algonquin Park; successful advocacy to establish Lady Evelyn, Killarney, and Quetico as wilderness parks; and improvement of logging and forest planning practices on public lands in Ontario.

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Executive Summary

Roughly 90 percent of the area logged in Canada each year is harvested using clearcut logging.[1,2] In boreal regions in particular, clearcutting has been justified with the ecological rationale that it provides a way of creating young, even-aged forests, which are naturally abundant in the boreal.

However, it has become clear that a one-size-fits-all approach to forestry is not well suited to even large disturbance-driven ecosystems like the boreal. Indeed, some jurisdictions, companies and researchers now acknowledge the limitations of clearcut logging and the differences between natural disturbances, such as fire, and the impacts of clearcutting.

A new vision for forestry in boreal forests has been developed and expressed through the National Boreal Standard of the Forest Stewardship Council (FSC). In addition to setting standards for responsible forestry that address social issues, including Aboriginal rights, the FSC standard defines a new approach to forestry that places greater emphasis on the conservation of key ecological values. This includes the completion of protected areas networks, the maintenance of old growth and intact forests, higher levels of retention in clearcut stands and the protection of High Conservation Value Forests.

This report fits into this overall vision. Our intent with this report is to promote greater variability in the harvesting and renewal of our managed boreal forests, a variability that is inherent in natural systems but which has been historically overlooked by the widespread application of clearcut harvesting.

In this report, we explore ways in which alternatives to traditional clearcut harvesting can support wildlife conservation goals in boreal forests. As well, we describe the effects of clearcut logging on boreal forests and their wildlife, summarize recent changes in forest management philosophy and outline the basis of these changes in recent research.

Our review of alternative silviculture approaches emphasizes the degree to which these have the potential to conserve important habitat features. We review important stand-level habitat features, their value to different species and the use of silviculture for their maintenance or restoration. We also make initial silvicultural recommendations for biodiversity conservation using the alternative approaches and summarize resulting policy and research issues.

Recommendations for policy reforms supporting alternative silvicultural approaches that provincial and territorial governments could implement include:

- Accelerate the adoption of alternative silviculture approaches within a well-defined adaptive-management framework that is supported by research.
- Revise information requirements for forest resource inventories and permanent sample plots to include measures of habitat structure.
- Revise harvest modeling approaches to incorporate alternatives to clearcutting and their potential effect on allowable cut.

We also recommend that some silvicultural innovations can be widely adopted immediately:

- Underplanting aspen or birch with white spruce.
- The use of pre-harvest scarification under canopies of red or white pine to be harvested using seed tree (red pine), group shelterwood (red pine, white spruce or black spruce in mixedwood stands) or uniform shelterwood (white pine).
- Careful logging (HARP / CLAAG) to conserve advanced regeneration and forest structure, providing it is done using smaller machines with an average of 25% of the stand in cutting trails.
- Uniform or strip shelterwood to promote regeneration of white spruce or paper birch from seed
- Modified clearcutting with significant amounts (10-50%) of residual forest retention on extended or variable rotations that allow characteristics of old forests to develop.
- Planning for the retention of present and future

snags and coarse woody debris within all silvicultural systems.

We recommend that some silvicultural innovations should be applied experimentally and then be applied more broadly if results demonstrate success at achieving silvicultural and wildlife objectives:

- Uneven-aged silviculture in lowland black spruce.
- Single tree and group selection in old boreal forest stands. In absence of demonstrated success, the use of reserves and lengthened rotations continues to be the preferred method for retaining old growth in the forest landscape.

We recommend that the following research objectives be pursued under an adaptive management framework:

- Establishing predictive relationships between levels of silvicultural intensity and habitat conservation,
- Refining silvicultural and habitat conservation techniques in alternative systems,
- Investigating the transferability of alternative silviculture approaches between different parts of the country,
- Improving our knowledge of the relationships of individual species with habitat,
- Investigating silviculture-habitat relationships in longitudinal studies that study the consequences of forest practices for complete rotations or longer, and
- Improving our knowledge of poorly studied taxonomic groups.

1.0 Introduction

About one million hectares of Canada's 119 million hectares of commercially managed forests are harvested every year. Roughly 90 percent of this area is harvested using clearcut logging.[1, 2] In fact, clearcut logging has become the primary forest disturbance in Canadian forests that are allocated for industrial forestry.[3] For example, between 1951 and 1995 in Ontario, 6.6 million hectares of forest were harvested by clearcutting, versus two million hectares that were burned by wildfire.[4]

In boreal regions in particular, clearcutting has been justified with the ecological rationale that it provides a way of creating young, even-aged forests, which are naturally abundant in the boreal. Clearcutting has also often been justified by its supposed similarities to the effects of stand-replacing wildfires[5a].

A large body of evidence now undermines this assertion[6, 7, 8] (see Table 1). We now know that boreal forests experience a wide variety of natural disturbances in addition to fire, such as windthrow and insect outbreak. Some forest stands may also survive for 200-400 years without burning.

This variety in natural processes means that many Canadian boreal forests have a greater diversity of age classes and habitats than was previously assumed. At the landscape level, this diversity can be found in the form of a great variety of forest stand types,[17, 18] at the stand level in the form of complex forest canopies consisting of trees of different ages[19] and on the ground level in the form of individual trees, snags and large woody debris.[20] These findings confirm 20 years of research demonstrating that a full range of forest age classes and habitats must be retained to support the full diversity of forest wildlife.

Some of the ecological costs of clearcutting are a result of its almost universal use and the near-absence of alternative silvicultural strategies. By transforming and simplifying forest habitats and creating excessive amounts of edge, clearcutting has the potential to substantially reduce the supply of habitat features that support healthy wildlife populations.[2, 16] These effects are aggravated by the fact that traditional forest management planning often targets older stands for cutting first. Future cuts are also planned to occur at intervals that are shorter than natural fire cycles — a practice that may prevent clearcut forests from ever returning to a natural forest structure.

From an economic perspective, clearcutting has allowed for the efficient use of large machines to produce high volumes of wood for increasingly large and automated mills. Over the past four decades, clearcutting has been central to an overall forest industry trend towards increasing the mechanization and reducing the labour costs of forest management. The major benefits for using the clearcut system are therefore economic, not ecological.

However, despite these economic advantages, it has become clear that a one-size-fits-all approach to forestry is not well suited to even large disturbance-driven ecosystems like the boreal. Indeed, some jurisdictions, companies and researchers now acknowledge the limitations of clearcut logging. They are beginning to move forest management away from traditional timber-focused management toward practices that are more in tune with the developing model of Ecosystem Management.

A new vision for forestry in boreal forests has been developed and expressed through the National Boreal Standard of the Forest Stewardship Council (FSC). In addition to setting standards for responsible forestry that address social issues, including Aboriginal rights, the FSC standard defines a new approach to forestry that places greater emphasis on the conservation of key ecological values. This includes the completion of protected areas networks, the maintenance of old growth and intact forests, higher levels of retention in clearcut stands and the protection of High Conservation Value Forests.

In this report, we explore ways in which silvicultural alternatives to traditional clearcut harvesting can support wildlife conservation goals in boreal forests. We describe the effects of clearcut logging on boreal forests and their wildlife, summarize recent changes in forest management philosophy and outline the basis of these changes in recent research.

The stand and landscape levels of management are both important in wildlife management. However, in this report we focus on stand-level practices, because this is where silvicultural practices directly influence local habitat quality.

Therefore, our review of alternative silviculture emphasizes the degree to which these approaches have the potential to conserve important habitat features. To this end, we review important stand-level habitat features, their value to different species and the use of silviculture for their maintenance or restoration. We also make initial silvicultural recommendations for biodiversity conservation using the alternative approaches as well as summarizing policy and research issues.

Some of the silvicultural alternatives that we present have had their economic and ecological viability demonstrated in operational trials. By defining these new approaches and describing their potential benefits to wildlife, we hope to encourage their application at broader scales. Our intent is to promote variability in the harvesting and renewal of our managed boreal forests, a variability that is inherent in natural systems, but which has been historically overlooked by the widespread application of clearcut harvesting.

Table 1. Summary of major ecological differences between the effects of forest fire and clearcut logging		
Fire	**Clearcut Logging**	**References**
Forest age classes approximate a negative exponential distribution (see Figure 1). Under this distribution, a proportion of stands will always be older than the mean fire-return interval, no matter what the fire regime.	Age distribution in managed forests is manipulated to allow equal areas to be harvested over time. This system necessitates a “rectangular” age class distribution with stands older than the rotation age being eliminated from the landscape.	9, 10
Forest fire sizes in Canada range from 0.1 ha to 1.4 million ha.	Ninety percent of clearcuts in Ontario occupy less than 2,000 hectare. None approximate the size of the largest or smallest fires.	4a
In large burns, the ratio of edge habitat to the area burned is lower than in clearcuts. Edges are also “softer”. The effects of fire blend into the living forest, leaving a ragged edge.	In Ontario, the length of forest-clearcut edges is 10 times greater than that created by burning. They impose a pattern of sharply defined geometric edges over the landscape.	4b
Fires leave large areas of dead and scorched standing trees in the landscape.	Traditional clearcutting removes all standing trees. Although new management prescriptions often call for retaining 1-25 snags and potential snags per hectare, snag densities left by fire can be up to 10,000 stems per hectare.	2
Abundant coarse woody debris (CWD) accumulates following fire.	CWD can be reduced by over 90 percent after the first clearcut and further reduced in later rotations	2
Fires are irregular in shape, and leave legacies of forested “islands” within larger burned areas.	Clearcuts leave few forest islands or peninsulas.	6, 11
Fires are not associated with the building of roads or increased access for hunters and fishers.	Forest management leaves a network of roads across the landscape. Roads increase access to wildlife for both human hunters and predators and add previously unknown stresses and dangers — such as traffic noise and collisions — to those that are already suffered by wildlife.	12
In conifer-dominated stands, the new stand is often dominated by the original species.	In logged stands, conifers are often replaced by intolerant hardwood pioneers, such as aspen or by mixedwood.	13, 14

2.0 Clearcut harvesting and its ecological effects

2.1 The clearcut silvicultural system

As one of the family of even-aged silvicultural systems, the clearcut system replaces the original stand of trees with a generation of trees all of the same age.[21a] In a traditional clearcut, all commercially valuable trees are removed from the stand at the same time.[22] The forest is either allowed to regenerate naturally from seed sources in the surrounding forest or to preferred commercial species via planting at specified densities. A number of variations on the clearcut system (see Section 5) involve retaining individual trees or groups of trees in cutblocks, either as seed sources for regeneration or to serve habitat-retention objectives.


Clearcutting is the most common harvest method in boreal forests.

2.2 The ecological effects of clearcutting

2.2.1 Species change in clearcut stands

A clearcut boreal forest that has been left to regenerate naturally is often composed of different species than those that were present in the pre-harvest tree community. Many formerly pure coniferous stands have been converted to mixedwoods or pure hardwoods following clearcut logging.[13,14,23,24] Even stands planted with conifers have a tendency to regenerate with greater proportions of hardwood trees[13].

In contrast, conifer stands burned by wildfire typically return to their former species composition because cones on standing dead trees inundate burned sites with millions of seeds per hectare[24,25] (see Table 1). Clearcutting-induced changes in forest composition may therefore constitute a significant long-term threat to wildlife species that are dependant on or have a strong preference for conifer-dominated boreal forests.

2.2.2 Stand age, disturbance and habitat supply

In commercial forests, the economic rotation age (the age at which the rate of growth in timber volume reaches its peak) is often less than the time that would elapse between successive fires,.[29]and less than the time required to develop old-growth characteristics. A traditional approach to forest management would focus on harvesting forests when they reach peak volume. Therefore, the proportion of old-growth forest that would be present under natural conditions will tend to be reduced in clearcut commercial forests.

For example, timber supply planning in Ontario is now done on the basis of an "eligibility age" for cutting. This age is generally older than the economic rotation age. However, because timber supply models are set to maximize wood flows over each planning period, older stands will tend to be cut as soon as possible. Older forest stands will therefore continue to be lost under "business as usual" forest planning.[30] Animals that depend wholly or partly on the habitat features of old forest stands may therefore lose critical habitat in landscapes where the supply of old forest stands has been reduced by logging.

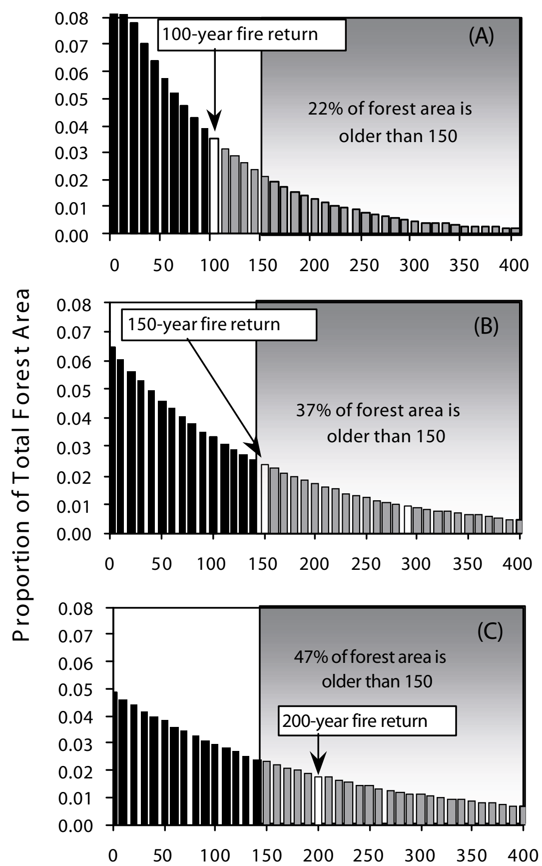
By contrast, in forests disturbed only by wildfire some forest stands will always be older than the average time between successive fires. If, as is generally assumed, all forest stands share the same probability of burning in any year, about one-third of a forested region should be made up of stands older than this average *fire-return interval*[26,27,28] (see Box 1).

2.2.3 Fragmentation and edge habitat

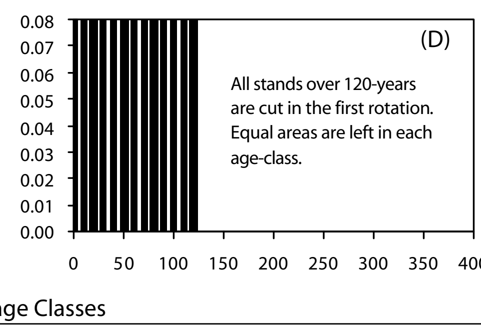
Landscape-level effects of logging also affect habitat quality at the stand level. Historic patterns of clearcut logging in Ontario have fragmented much of the intact mature forest into smaller patches. This reduces the area of interior forest habitat by increasing the proportion of forest-edge habitat. [31] Edge effects allow changes in environmental conditions to penetrate into "islands" of intact forest (Figure 1). For example, wind speeds and solar radiation increase in the forest interior, leading to the desiccation of leaf litter, increased soil temperatures, low humidity and altered species composition of the understory vegetation[32].

Box 1. Distribution of age classes under different fire regimes

Below we compare the proportional distribution of forest areas in different 10-year age classes under **(A)** a 100-year fire-return interval, **(B)** a 150-year fire interval, **(C)** a 200-year fire interval, and **(D)** in a forest managed on a conventional 120-year economic rotation. The reverse "J-shape" form of A-C is called the negative exponential distribution, and the theory was developed by Van Wagner.[28]



A consequence of the negative exponential distribution is that the average stand age equals the length of the fire-return interval, no matter how long or short it is. However, as the fire interval becomes longer, it can easily be seen that the form of the graph becomes flatter. This shows that as fire intervals become longer, more older stands "escape" from a fire for longer than the average fire-return interval. This has the consequence that greater proportions of the total forest area are likely to develop species compositions and forest structures that are thought of as characteristic of "old-growth forests".



These edge effects can penetrate for between 30 to 140 metres into temperate forest interiors.[32, 33] Smaller forest islands will therefore consist almost entirely of edge habitat. If edge effects penetrate for 30 metres into a stand, any circular forest island smaller than 0.3 hectares will consist entirely of edge. At 60 metres of penetration, there would be no core habitat in a 1.1-hectare forest island.

By increasing the length of edges between cut and intact forests in Ontario[4] (see Figure 2), clearcut logging has favoured species that prefer shrubby forest-edge habitats at the expense of those that inhabit the forest interior.[32, 33]

2.2.4 Roads

Wildlife biologist Reed Noss has written: "Nothing is worse for sensitive wildlife than a road."[34] Roads, which always accompany logging, cause some species to abandon their immediate vicinity and make others, such as woodland caribou, more vulnerable to predation.[35, 22] Other animals that are known to avoid roads include cougar, wolves, grizzly bears, black bears, Roosevelt elk and Massasauga rattlesnakes. Roads also inhibit the movement of smaller animals. Those that do attempt road crossings experience high rates of mortality, even on lightly traveled roads.[37] A study of roads in southwestern Quebec found more than 380 mammals killed over 116 days, along with 150 amphibians, 228 reptiles and 217 birds.[38]

Even where road densities are sparse, roads permit human access that can impact wildlife indirectly through disturbance and directly through hunting. Resource ministries that control logging roads can attempt to cut off access to haul roads. However, a recent report from CPAWS - Wildlands League and Sierra Legal Defence Fund found that access restrictions are frequently violated.[39] This finding has obvious implications for the security of wildlife populations and their safety from poaching or over-harvesting.

2.2.5 Stand-level impacts

Conventional clearcut logging removes the majority of habitat features that are present in mature forest stands. Even standing dead trees of no commercial value may be felled for safety or logistical reasons. For example, snag populations of 138-1,115 standing dead trees per hectare in mature Acadian forest are reduced to 0-25 trees per hectare in 25-year-old plantations.[2]

Clearcut logging also dramatically reduces the quantity of large-diameter logs (also called coarse woody debris or CWD) on the forest floor. Where whole-tree harvesting and slash piling are practiced, the weight of CWD can be reduced to one percent of its original extent in mature forest. Large logs and other CWD provide important winter shelter for a variety of small mammals and their predators and are nurseries for many herbs, insects, fungi and some forest trees.[40, 41]

2.2.6 Soil impacts

Although the full impacts are not yet known, long-term soil fertility may be reduced by successive clearcut harvests on the same site. Wildfire leads to the loss of carbon and nitrogen from forest soils, but clearcut logging removes substantial quantities of future soil nutrients by taking trees away from the site.[2] Harvesting debris (slash) is often piled or windrowed. Because 10 percent of a site's nutrient reserves can be concentrated in such piles,[42] this might lead to the impoverishment of nutrients across a site. Furthermore, if slash is piled but not re-distributed or burned, affected areas will not regenerate trees and the productive forest area under slash piles could be lost in subsequent rotations on the same site.

Poorly conducted logging operations can also lead to erosion due to the removal of ground cover, rutting by skidders and soil being exposed to erosion on steep slopes.

Figure 1. The effects of forest edges on interior forest environments (adapted from Matlack and Litvaitis[206]).

Note that total species diversity could be at a maximum at the forest edge because species from different environments commonly co-occur there.

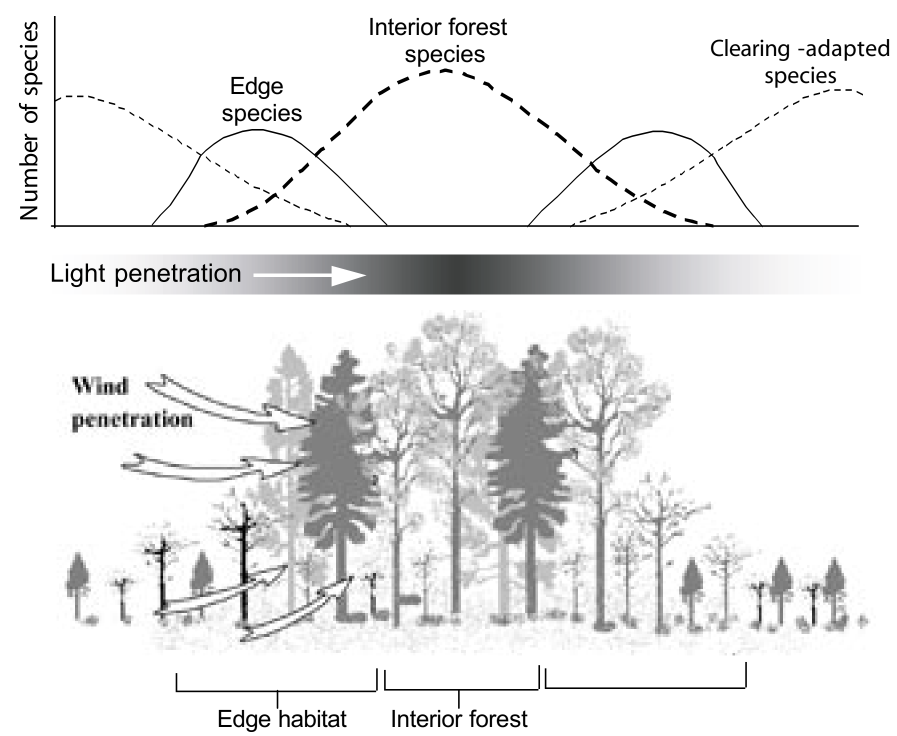
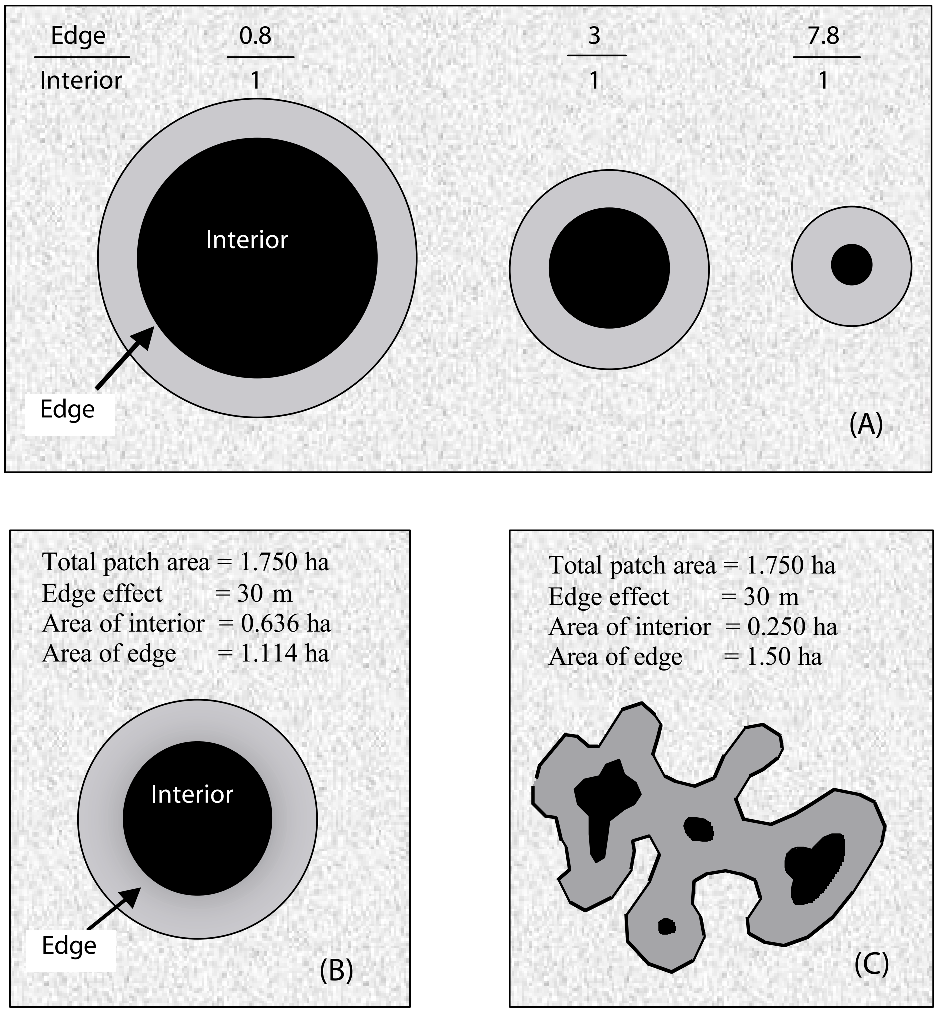


Figure 2. Consequences of fragmentation for the quantity of interior forest area and length of edge habitat

(A) As patches get smaller, the ratio of edge to interior habitat increases (assuming constant edge-effect width). (B/C) Both patches have an equal area and equal hypothetical penetration of forest edge. Differences in edge/interior proportions derive only from the shape of the patch. Adapted from Bannerman.[33]



3.0 Ecosystem management and habitat attributes

Under conventional clearcut silviculture, little attention is paid to the provision of important wildlife habitat attributes, such as large standing dead trees, woody debris or supercanopy trees. However, well-chosen silvicultural systems and stand-level practices can be used as the basis for sustaining wildlife habitat through time.[21b] Such an approach is inherent to ecosystem management, where the silvicultural mandate expands beyond what to harvest to include which trees and habitat features to leave.[43]

John Marriott, JEM Photography, www.wildernessprints.com

Martens require intact old forests. They would rather travel around, than through, large clearcuts.

Conventional forest management planning places timber production at centre stage with all other values being treated as constraints.[44] This timber-first focus has, however, been eroded over the last two decades as new management philosophies and legislation has introduced terms such as "sustainable forestry" and "ecosystem management" into the forester's lexicon.

Early signs of this shift towards ecosystem-based management were reflected in forest policy and legislation. In Ontario, this shift began in 1991 with the release of "Direction '90s", a set of directives for policy development written under the guiding concept of "sustainable development". This ecosystem-based approach to forest management in the province was further endorsed in both the 1995 *Crown Forest Sustainability Act* and the 1994 *Timber Class Environmental Assessment* decision.

The National Boreal Standard for the Forest Stewardship Council now provides a national example of how to better bring the diverse economic, social and ecological objectives to bear on forest management.

The core philosophy of ecosystem management requires forests to be managed as complete ecosystems, not just for the timber that they contain. Ideally, ecosystem management would involve managing timber, wildlife and other forest values in a single integrated system, rather than the current fragmented — and frequently completely separate management of trees, wildlife and water.[43]

In the section that follows, we discuss the types of natural attributes this new ecosystem-management approach must consider in the selection of silvicultural approaches.

4.0 Habitat attributes, habitat management and forest wildlife

4.1 The scale of habitat management

All animal species, from the smallest salamander to the largest moose, share certain fundamental habitat requirements. These include foraging habitat, areas in which to breed and to raise young, and places to shelter from predators and the elements. Animals such as bears and porcupines also need a sheltered place to hibernate. These habitat features must be managed at different scales, ranging from the stand-level provision of downed logs as winter shelter for squirrels to the conservation of large-scale habitat assemblages that encompass winter range and birthing grounds for caribou.

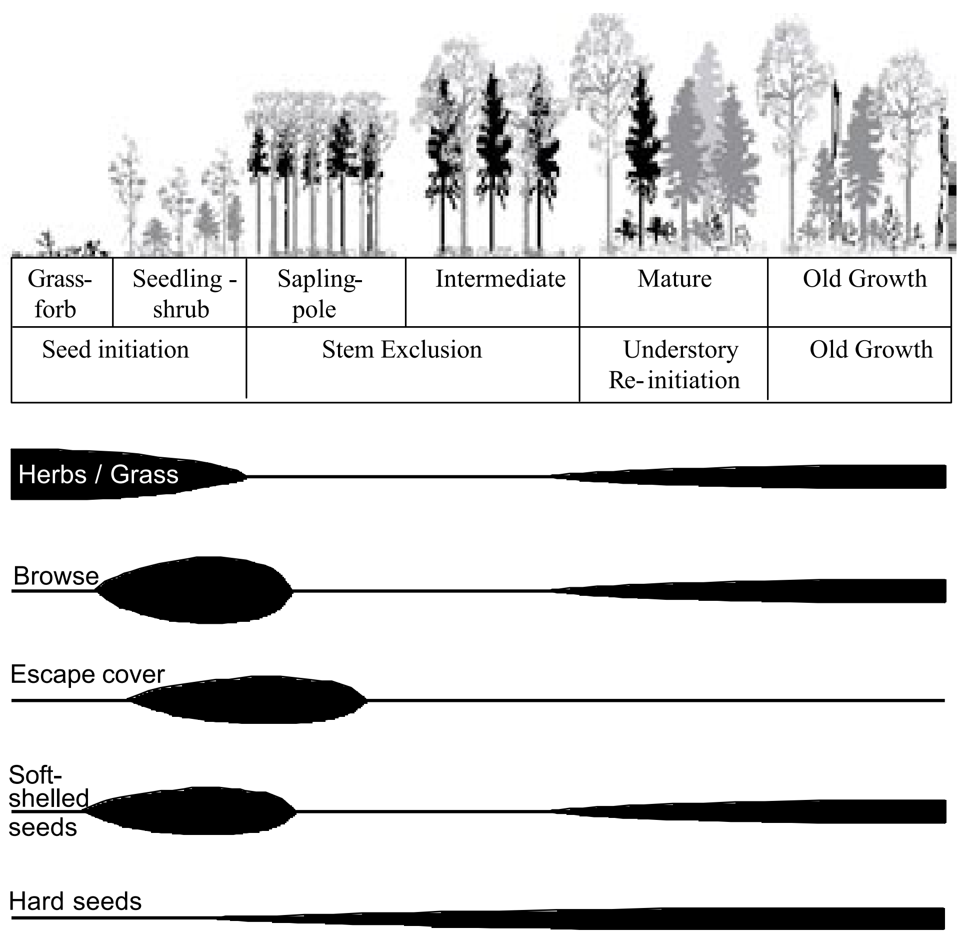
The availability of different types of habitat often depends upon the successional stage of a forest stand (see Figure 3). Forestry, therefore, affects the type and amount of habitat available. These affects are felt both locally within stands and through the impact of forestry on the distribution of stand age classes across whole landscapes.

The different habitat functions described in Figure 3 together with their associated age classes must be present in a species' home range if it is to survive. For example, moose preferentially feed in wetlands, burns and early successional stands in the spring, but during the winter they occupy closed, mature mixed-wood stands that provide thermal cover and browse.[47] Shortage or poor quality of these seasonal habitats can limit moose population densities.[48] The spatial distribution of age classes and habitats will also facilitate or inhibit the seasonal movements of animals between habitats.

Home range size is strongly related to an animal's body weight and feeding habits. Home-range sizes for vertebrates range from ≤ 0.5->10,000 hectares as body size increases[49] (see Figure 4). Distances dispersed by young mammals and birds after they

Figure 3. Idealized successional stages of a coniferous or mixed-wood forest and their relationship to various habitat attributes used by wildlife

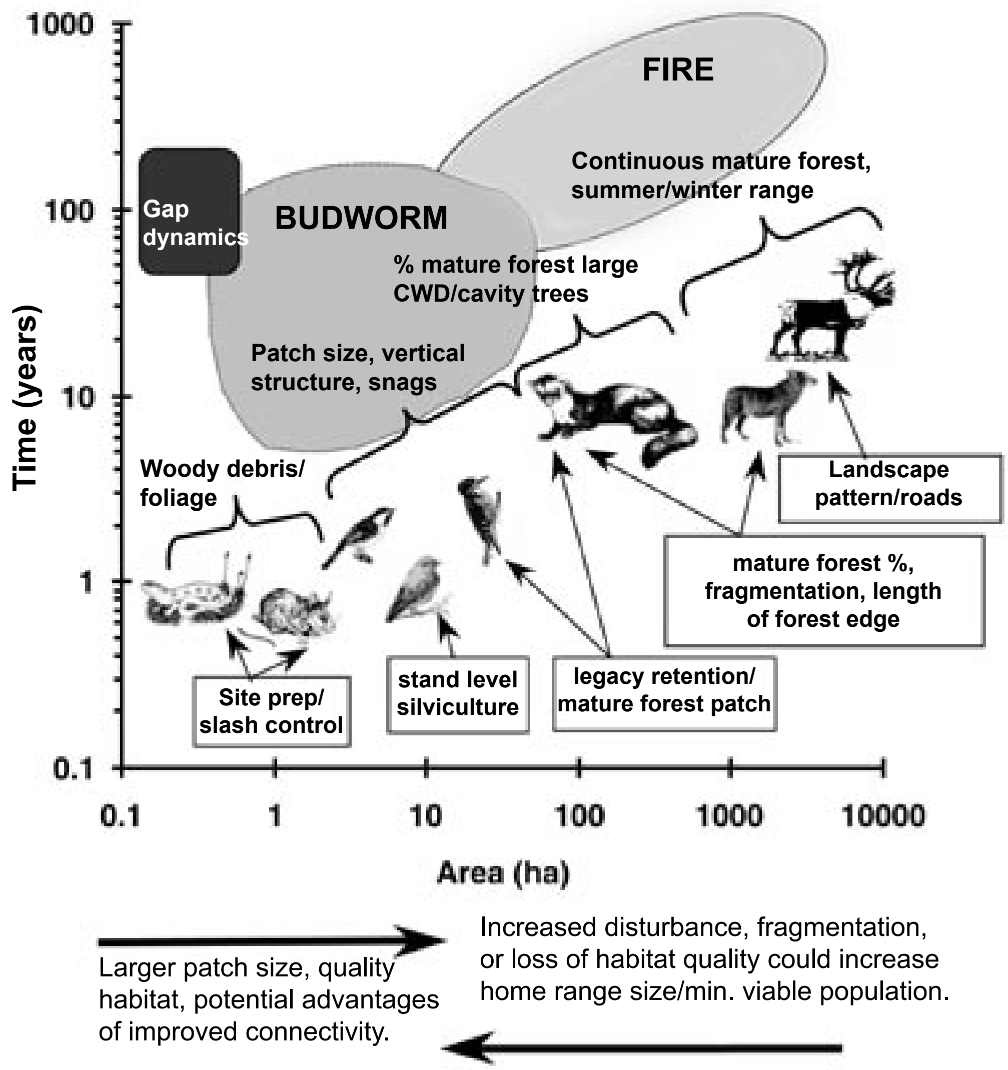
The stages shown by variable width black lines are general trends; the details will vary in different forests (adapted from Smith et al. 1997).



are weaned follow the same trend. For example, maximum dispersal distance for prairie voles is on the order of hundreds of metres, whereas lynx disperse up to 930 kilometres.[50] Therefore, small animals may live out their whole lives in a small forest stand, while the largest animals may range across hundreds of different stands.

Figure 4. Conceptual diagram illustrating the diversity of home-range sizes and the probable habitat attributes and management effects associated with them (adapted from Bunnell,[200] Spies,[18] and Voigt[56]).

The time axis relates to the return time for natural disturbances and the time frame for habitat occupancy by animals. Labelled parentheses show important habitat attributes at different scales; labelled arrows show influence of selected forestry practices at different scales.



The enormous range of scales at which different animals use habitat means that foresters must consider habitat quality at the scale of logs, stands and landscapes when they plan forestry operations. For wildlife, these decisions will affect both the quality of their home-range habitat and the relative "hostility" of the intervening landscape between residual habitat patches.

Landscape planning for large home-range species may take care of minimum patch-size requirements for small home-range species, providing that the full range of habitat types and age classes that would be naturally present is retained as part of this coarse-filter approach (see Box 2). The landscape plan must ensure that sufficient areas of these habitats with adequate connectivity are conserved to maintain viable species populations of the various species that use them. For example, if silvicultural practices maintain only small, isolated patches of old growth, species that rely on them may eventually disappear.

4.2 Stand-level habitat

4.2.1 Stand-landscape relationships

Intuitively, then, we might think that small creatures with small home ranges can have their habitat needs managed more easily than those with larger home ranges. Provided that populations do not become too isolated, stand-level practices such as the

Box 2. The coarse- and fine-filter approaches to habitat management

Coarse- and fine-filter approaches to wildlife-habitat management are conceptually different but represent complementary approaches to habitat management. The **coarse-filter** approach involves providing forest attributes (for example, snags, large coarse woody debris — also known as CWD, age classes in a landscape) in such a way that sufficient habitat is provided to support the majority of forest species. The coarse-filter approach has been thought to be particularly applicable to boreal forests, in which the majority of known species are thought to be habitat generalists; that is, although different species may have particular habitat preferences, they evolved in forests that burned periodically and were therefore subject to dramatic short-term changes in habitat quality.[51, 52, 53] An effective coarse filter will conserve natural landscapes that are sufficiently large to maintain species and natural processes, together with linkages that permit genetic interchange.[54]

The **fine filter** is necessary to provide for species that have special habitat requirements, that are endangered or vulnerable to disturbance or that act as "keystone" species in a landscape. At the level of a forest or landscape plan, coarse-filter requirements (see A below) would be planned in advance of providing the fine-tuning needed for the provision of fine-filter requirements (B) [55].

Considerations for (A) coarse-filter, and (B) fine-filter habitat[55]

Coarse Filter	Fine Filter
Forest composition • retain habitat within historic bounds of variability **Age-class structure** • retain range of age classes found under regional fire regime **Forest patch characteristics** • range of sizes • adjacency of different age classes • prescribed burns **Residual patches** • distribution of peninsular and island patches in burns • riparian buffers **Residual trees** • live cavity trees • snags and large coarse woody debris	**Vulnerable, threatened or endangered species** • patch size for caribou • site-specific habitat (e.g., bald eagle and red-shouldered hawk nesting sites) • landscape-level habitat supply (e.g., caribou, red-shouldered hawk) **Featured or keystone species** • deer-yard management plans • site-specific habitat protection (e.g., heronries, goshawk nests, fish-spawning channels) • landscape-level habitat supply (e.g., marten, pileated woodpecker)

dispersal of logging debris or provision of residual tree patches may effectively conserve habitat for voles, squirrels and other small species. Of course, attention has to be paid to the dimensions and qualities of these habitat features as well as to their area or volume.

However, the need for caution with this approach and the importance of landscape-level thinking can be illustrated with the example of songbird communities. Bird communities *similar* to those found in continuous forests can breed in forest fragments of 10 hectares or less[56a]. But the persistence of these communities depends on the character of the surrounding habitat and the time that has passed since the fragment or patch was created.

For example, where the original forest cover has been fragmented by agriculture or cutting, species diversity and population density may increase temporarily as birds disperse into fragments from logged areas.[57] But after one to two years, warbler species that prefer intact mature forests were markedly reduced in forest fragments in Alberta.[58]

Small habitat features also influence the movements and activities of species with large home ranges. Although many species with large home ranges are large-bodied predators, their herbivore prey often have small bodies and home ranges. Predators will therefore be affected by the quality of small-scale habitat features used by their prey species. A classic example of this linkage is the dependence of marten on the local abundance of large downed logs because these logs provide vital winter shelter for the squirrels and red-backed voles that are the marten's preferred prey.[59, 60, 61, 62]

For herbivores with large home ranges, such as moose and woodland caribou, sheer body mass and the low nutritional value of the available forage require them to exploit large landscapes. However, key habitats, such as islands, peninsulas or open peatland calving grounds used by caribou[63] are strictly local resources that may be used repeatedly for many years. The ecosystem integrity and the quality of linkages between these local areas and other habitats therefore require special consideration in forestry planning.

4.2.2 Stand-level diversity

In the boreal forest, mixed-wood and mature stands may support high biological diversity, in part because they are structurally more diverse than other stand types.[64] The vertical stratification of foliage, fruit and insect prey in mixed-species stands creates habitat niches that birds and arboreal mammals use for feeding, shelter from predators and nest parasites, territorial assertion and mating.[19a]

Recent research in Saskatchewan shows that songbird diversity is particularly high in white spruce and aspen dominated mixedwoods.[65] Figure 5 summarizes these findings and illustrates the importance of maintaining within-stand structural diversity and a variety of stand types if the full range of species is to be conserved.

Stands of many ages are also important for maintaining the full species diversity of landscapes. For example, magnolia warblers use both young and old forests, but alder flycatchers and chestnut-sided warblers primarily use young stands.[52] An extreme example of age and stand-type specialization is that of the Kirtland's warbler, which can only breed successfully in large stands of young jack pine.[42]

Many boreal animals are adaptable to a variety of stand types and ages. However, even habitat generalists may have preferences for particular habitat features within stands. Cape May, Tennessee and bay-breasted warblers preferentially use jack pine-mixedwood stands that support high balsam fir and white spruce cover,[66] probably because spruce and fir support large numbers of spruce budworm and other lepidoptera.[65] Other preferential associations include those of chipping sparrows with black spruce, yellow-bellied sapsuckers with larch trees[67], black-throated green warblers with conifer understories[209] and Swainson's thrushes with white birch.[66]

Although they feed and roost in a range of environments, woodpeckers depend upon the presence of certain critical stand-level habitats for their survival. Pileated woodpeckers have an absolute need for mature forest stands with large (≥ 40-centimetre diameter) aspen in various stages of decay for nesting and roosting.[68] Similarly, black-backed and three-toed woodpeckers gather in recent burns to feed. Black-backed woodpeckers feed on the larvae of wood-boring beetles that remain in burned trees for long periods of time and therefore feed in burned stands for up to 16 years. Three-toed woodpeckers, by comparison, abandon burned stands after three to eight years because they feed on the larvae of bark beetles, which are transient in burns. They are also found in old-growth stands where senescent trees support bark beetles.[67]

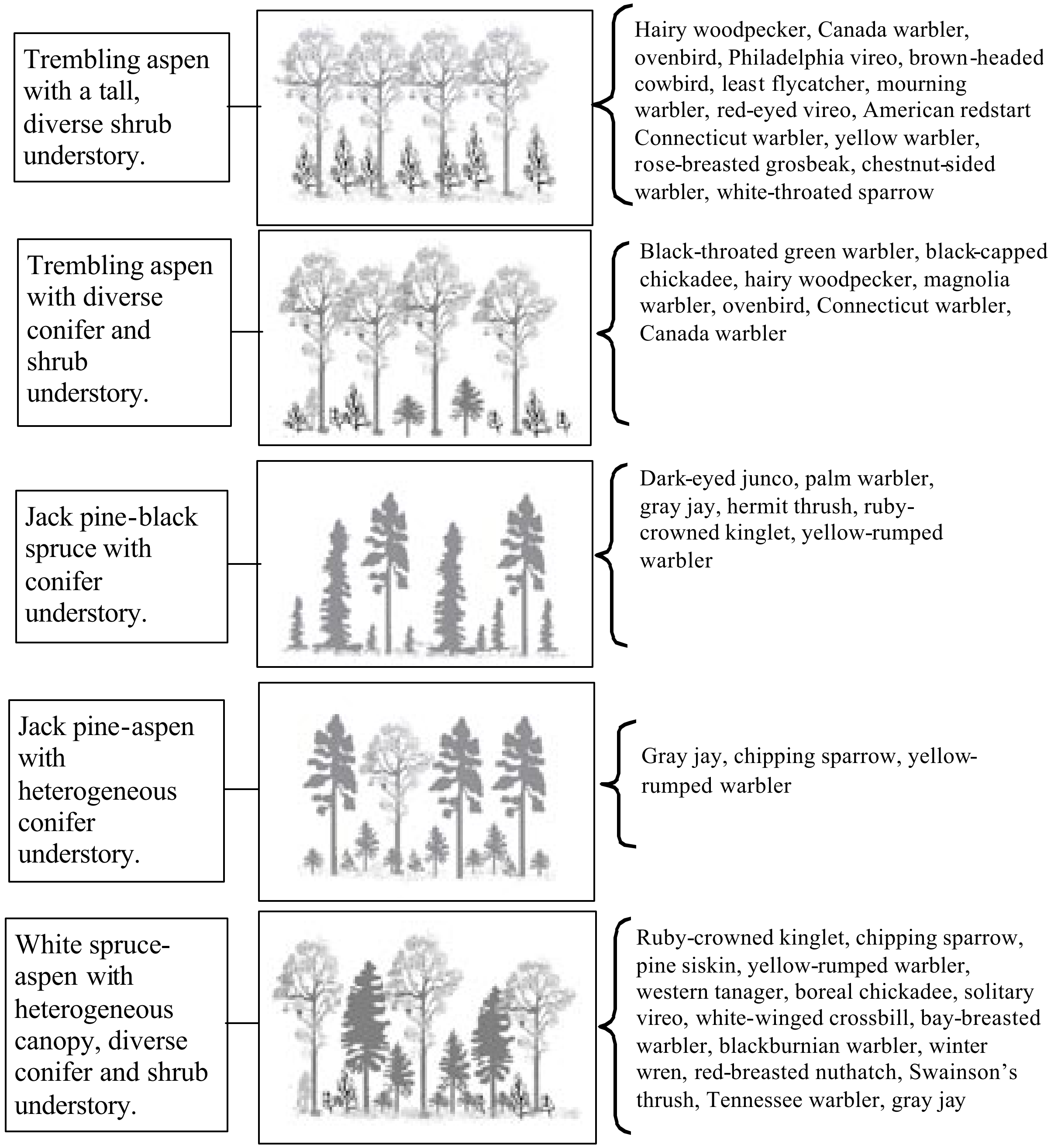
Therefore, in addition to maintaining all stand types, ages and successional stages, silvicultural planning must incorporate the provision of standing dead trees in burned stands to provide critical foraging habitat for these woodpecker species.

4.2.3 Old stands and forest structure

A walk through an old boreal forest stand would reveal a complex world of dead trees, dense patches of young conifers interspersed with larger hardwoods, and light-filled gaps caused by the deaths

Figure 5. Habitat partitioning by songbirds among boreal mixed-wood stands identified by TWINSPAN analysis in Saskatchewan

The diagram is based on species compositions and structural attributes reported by Hobson and Bayne.[65] Only the strongest associations of birds to stand type (i.e., most-preferred habitat) are shown.



of older trees[69]. These features create vertical and horizontal diversity in the forest canopy, which, in turn, encourages diverse biological communities. For this reason, there have been many calls for the retention of old-forest patches to become a standard part of forest policy in numerous forest ecosystems.[16, 70, 72, 73, 74, 75, 76]

The successional dynamics of old mixed-wood stands is dominated by the mortality of small groups of trees, which tends to increase the horizontal and vertical complexity of stands.[78] On the other hand, the volume of large-diameter, high-quality aspen snags and seven-centimetre CWD ≥

peaks 150 years and 100 years respectively after a fire.[77] Since large snags and logs, especially aspen, are key resources for many species, one can *tentatively* assume that 100-150-year-old mixed-wood stands would have the greatest capacity to support snag- and CWD-dependant fauna.

Old-forest stands also provide valuable refugia for little studied, but important components of forest biodiversity. For example, lichens are probably a keystone resource in boreal forests — many other species within their biological community are directly or indirectly dependent on their presence. Although they might seem like only a veneer on the branches of boreal trees, their biomass is considerable. In northern Saskatchewan, 145-231 kilograms of lichens per hectare (e.g. *Alectoria*, *Evernia* and *Usnea* spp.) can grow on black spruce and up to 472 kilograms per hectare can grow on jack pine.[79] Lichens form the base of food webs in which lichen-eating invertebrates are primary consumers and are, in turn, devoured by small predators, such as foliage-gleaning songbirds.[80]

In Scandinavia, tits (relatives of chickadees) cache food items underneath lichen mats on branches.[81] Many birds, including the common merganser, red-shouldered hawk, ruby-throated hummingbird, eastern wood pewee, boreal chickadee, golden-crowned kinglet and blackburnian warbler, construct their nests partially or completely from lichens.[80]

Forest management has discernible effects on lichen communities. In Sweden, managed stands of Norway spruce supported less lichen biomass, fewer invertebrate species and up to five times fewer invertebrates per branch than unmanaged mature forests.[81, 82]

Some lichens are adapted to grow on particular tree species or in late successional stands.[83] The biomass and species diversity of lichens will likely become important future indicators of sustainable forest management, reflecting their important ecosystem role.

4.2.4 Fragmentation and forest edge

The creation of edge effects and the fragmentation of intact forests are complementary processes. Edge effects can be caused by logging, road building, and forest fire or even by the death of a small group of trees. Fragmentation occurs when disturbance, be it human-caused or natural, becomes so pervasive that formerly intact forests are reduced to "islands" in a "sea" of some other land-use or vegetation type. This in turn affects everything from habitat connectivity to the proportion of edge and interior species.

At the point where intact forest areas become islands, the rate of species loss may increase dramatically over time. In fact, a synthesis of fragmentation studies suggests that species loss will accelerate as the proportion of suitable habitat in a landscape falls below about 30 percent.[84] Such disproportionate losses reflect the synergy resulting from the combination of various edge effects, including the decrease in the absolute area of suitable habitat and the increase in distances between suitable habitat patches.

Fragmentation and edge effects also potentially impact forest wildlife by increasing competition, predation and parasitism. Interior forest birds may lose out in competition with semi-colonial songbirds that occupy scrubby edge habitat. Where agricultural land creates edge habitat, parasitism by brown-headed cowbirds and direct nest predation by crows may be leading causes of nesting failure in songbirds.[32a] One study found that predation by squirrels was significantly higher in farm woodlots than in continuous or logged forests,[85] which indicates that the character of the overall landscape may influence the effects of edges on species.

Habitat fragmentation has both local and landscape-scale effects on species with large home ranges. Local effects include modification of animal movements and reduced winter survivability. For example, marten will modify their activity patterns to avoid clearcut blocks immediately after their creation.[86] As they seldom venture more than 500-

1,000 metres from uncut forest,[59] marten will travel around, rather than through, large clearcuts.

At the landscape scale, marten home ranges will therefore become larger in response to fragmentation. This has been observed partly because their prey capture rates in sub-optimal second-growth forests are reduced for up to 40 years.[60, 74]

In contrast to marten, moose make extensive use of edge habitats in recovering cutblocks and burns, although they avoid fresh clearcuts.[47] However, increased snow pack in small fragments reduces the value of coniferous forest islands as winter habitat for moose and deer.[75] Narrow buffers between adjacent clearcuts or small residual islands will therefore be of little use as winter habitat for moose and deer.


Gary McGuffin

Small patches may lack interior habitat.

Woodland caribou arguably require larger home ranges and, therefore, more extensive and careful landscape-level planning than any other large animal in North America. The small caribou bands that roam the northern boreal forest have home ranges of 100-10,000 square kilometres and require core winter habitat areas of 26-282 square kilometres. At these scales, landscape-level management must be coordinated among forest license holders because suitable winter range, calving habitat and travel corridors must be secured across huge areas. Planning should also take into account habitat availability for 80 years or more,[12] because favoured habitat attributes (e.g., arboreal lichens in old jack-pine stands) take a long time to develop.

4.2.5 Residual trees

Forest fires leave islands of live and damaged trees that can occupy up to 50 percent of the burn area.[2]

On the other hand, clearcut logging leaves smaller patches of intact forest as buffers between adjacent cutblocks and around bodies of water. What value do these residual habitats have for wildlife? How big does a residual forested patch need to be to provide habitat and how many trees can be removed during a partial cut before habitat quality is compromised? For forest patches, the answers to these questions depend on the size of patches and the extent to which the surrounding habitat has been altered. In the case of partial harvesting, the capacity of the stand to support wildlife will depend on the extent to which the residual trees maintain habitat structures and environmental conditions that were found in the uncut stand.

Mammals and ground birds respond to the creation of residual forest patches and buffers according to home-range size and behavioral characteristics. Spruce grouse and snowshoe hares, species with home ranges ≤ 25 hectares, were absent for one to four years from areas that were clearcut with the protection of advanced regeneration.[88] Moose and marten, which have home ranges ≥ 5 square kilometres, avoided clearcut areas with sparse shrub layers, but continued to use the 60-100-metre buffers separating clearcut areas. Marten and moose may supplement the habitat lost to cutting by shifting to the uncut areas of their home range, underscoring the relationship between stand-level treatments and the arrangement of suitable habitat in the landscape.

Some small home-range species (e.g., deer mice) may have stable or increasing populations in clearcuts. For these species, habitat attributes may be perceived at scales smaller than the smallest residual forest patch. Therefore, they may not perceive a drastic change in habitat if key microhabitat resources, such as coarse woody debris, remain abundant. It is also possible that deer mice and other species that are positively correlated with clearcutting are specialists of early successional habitats.[89, 90, 91]

The size of forest fragments affects the absolute numbers of animals that a residual forest patch can support and the species composition of the wildlife community. For example, songbird abundance increased by 30-70 percent in 20-, 40-, and 60-metre wide riparian buffers for a year following the clearcutting of a surrounding balsam-fir forest. After three years, forest interior birds, such as golden-crowned kinglets and blackpoll warblers remained abundant in 60-metre wide strips, but "edge" species such as dark-eyed junco and American robin dominated 20- and 40-metre wide strips.[92]

Connectivity between residual forest patches and distant tracts of intact forest improves as the clearcuts surrounding forest islands regenerate. With the exception of cavity-nesters, forest-bird communities begin to re-establish themselves in old clearcuts when they reach the sapling stage of regeneration.[93] As cutblock environments regenerate, forest islands could therefore provide core breeding habitat from which fledglings disperse to less suitable, but still habitable, young forest.

Conversely, as the cutblock environment becomes less hostile, mature forest species might spread to the residual forest patches from larger blocks of nearby mature forest. Data from a 60-year chronological sequence showed that bird communities in large and small residual forest patches were becoming similar to those of mature forests 30 years after logging. On the other hand, species that require mature mixedwoods (e.g., yellow-bellied sapsucker, least flycatcher, magnolia warbler) were absent or rare in forest islands even 60 years after the initial harvest.[94]

4.2.6 Snags, cavity trees, and coarse woody debris

The value of snags, cavity trees and supercanopy trees to wildlife depends on the tree species, its size, state of decay, and the environment that surrounds it (see Figure 6). These factors also influence the quality of the downed logs that are produced when snags fall.

Very large numbers of forest animals use dying or dead wood at every stage of the decay cycle (Figure 6). In the Great Lakes-St. Lawrence Region, 47 out of 181 vertebrate species use cavity trees and 64 of these use coarse woody debris (CWD). Three species — the bald eagle, golden eagle and black bear — use very large supercanopy trees.[75] In the boreal forests of northeastern Ontario, 10 primary cavity-nesting birds (those that directly excavate cavities for themselves) indirectly support 22 secondary cavity-nesting birds and 14 secondary cavity-using mammals[95a] (see Table 2 and Figure 6). CWD is also important to invertebrate populations such as ground beetles.[210]

By creating cavities in trees softened by heart-rot, primary cavity nesters play a pivotal role in supporting birds and mammals that depend on cavity trees.[96, 97] Yet in most forests, including Canada's boreal forests, the primary cavity nesters are among the species most threatened by current forestry practices[98, 99]

To manage cavity trees, snags and CWD, we must understand the processes of senescence and decay. Figure 6 illustrates these processes for standing trees and CWD in coastal Douglas fir stands, but the basic scheme is valid for most temperate forests.

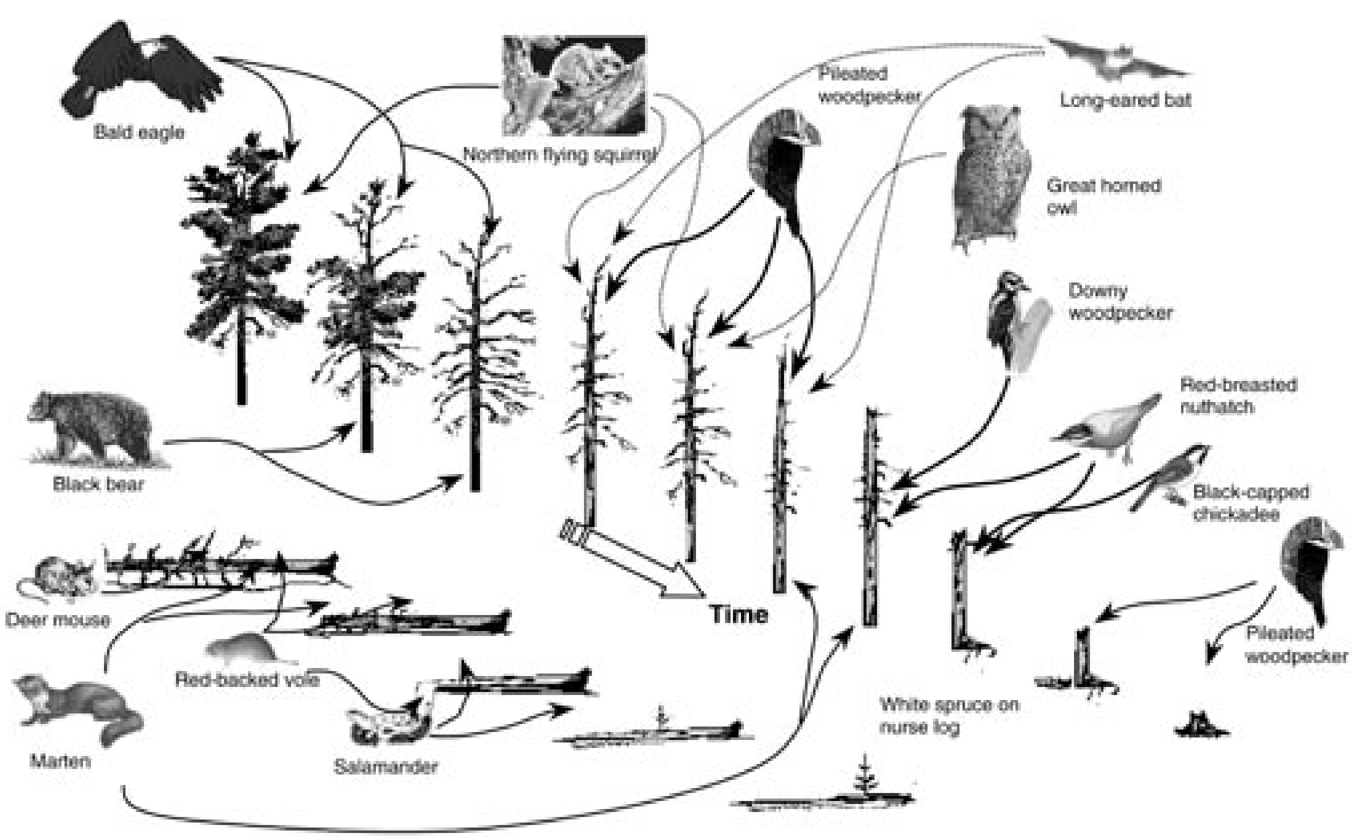
As a tree senesces and decays, changes in its overall architecture, wood texture and chemistry also change the habitat attributes that it provides. The bare top of a supercanopy tree becomes a lookout perch for bald eagles and broad-winged hawks. As decay fungi soften the wood, pileated woodpeckers, downy woodpeckers and even weak cavity nesters, such as black-capped chickadees, excavate nesting cavities within the snag. Secondary cavity users exploit existing cavities that are often the abandoned nest sites of primary cavity nesters. Very large basal cavities hollowed out by decay fungi are used as hibernation sites by black bears.

Table 2. List of primary and secondary cavity users that are known from northern Ontario[95]

Primary cavity nesters	Secondary cavity users		
	Birds		Mammals
Downy woodpecker	Wood duck	Boreal owl	Northern long-eared bat
Hairy woodpecker	Black duck	Northern saw-whet owl	Little brown bat
Pileated woodpecker	Common merganser	Great crested flycatcher	Silver-haired bat
Common flicker	Bufflehead	Tree swallow	Least chipmunk
Black-backed woodpecker	Hooded merganser	White-breasted nuthatch	Red squirrel
Three-toed woodpecker	American kestrel	Brown creeper	Northern flying squirrel
Yellow-bellied sapsucker	Great horned owl	House wren	Deer mouse
Black-capped chickadee	Northern hawk owl	Winter wren	Porcupine
Boreal chickadee	Barred owl	Eastern bluebird	Black bear
Red-breasted nuthatch	Merlin	European starling	Raccoon
	Common goldeneye	Purple martin	American marten
			Fisher
			Ermine
			Long-tailed weasel

Figure 6. Simplified animal community of the wood decay process (adapted from Hunter[207] and McComb and Lindenmayer[208])

Heavy arrows indicate primary cavity nesters, solid arrows indicate feeding, nesting or hibernation, and dotted arrows indicate secondary cavity users.



House wrens, brown creepers and northern flying squirrels use cavities for shelter, nesting or hibernation. Swifts and bats may roost communally in large cavities.[100]

When a standing dead tree falls it continues to provide habitat for terrestrial animals. Logs in various states of decay provide moist microhabitats and shelter for amphibians, foraging sites for fungus-feeding voles, drumming perches for ruffed grouse and nesting sites and maternal dens for martens and fishers.[75, 100] Large logs in early stages of decay provide critical habitat for marten and their prey. During winter months, small mammals remain active beneath the snow.[59] Large logs accumulate snow in drifts that can shelter small animals from cold and provide unseen travel corridors. Marten hunt in these areas where voles and squirrels are more likely to be found.[61, 62]

Burned areas can contain hundreds of standing dead trees.

The variety of substrates created by tree falls and log decay can promote increased diversity of some plant groups, such as mosses.[101] Finally, both fresh and rotten moss-covered logs provide seedbeds for white spruce and eastern white cedar in boreal mixed-wood stands.[102]

4.2.7 Burned areas

Wildfire, the major natural disturbance in boreal forests, leaves distinct biological legacies to the future forest. Biological legacies are important habitat structures that are carried over from the original to the disturbed stand. These include living and dead seed trees that provide for regeneration and determine the species composition of forest stands.[6] Living “forest islands” have been found to cover, on average, 24 percent of a burned area,[55] but patches of mildly scorched trees can cover up to 50 percent of a burn.[10] These larger patches are important in spreading seed throughout the post-fire stands. They may also provide important refuges for animals and birds plus sources for future cavity trees for creatures as diverse as woodpeckers, owls, bats and marten.[10]

However, boreal forests in much of Ontario and Quebec are not composed entirely of even-aged, fire-origin stands. In stands that escape fire for prolonged periods, canopy gaps produced by the deaths of groups of trees replace fire as the leading cause of forest disturbance. Caused by spruce budworm outbreaks, windthrows and wood-rotting fungi, these canopy gaps allow new generations of pioneer trees, such as trembling aspen, to coexist with shade-tolerant conifers, such as eastern white cedar, in the same stand.[7, 103, 104, 105, 106, 107] This will also be true of boreal forests in other parts of Canada to a greater or lesser extent depending on the local fire regime.

5.0 Alternative silviculture approaches for Canada's boreal forests

Under the ecosystem-management philosophy, the management or simulation of natural disturbance regimes has become an important tool for forest management. Fires, windthrows and insect outbreaks are defining processes that drive the dynamics of regeneration, nutrient recycling in soils and the distributions of tree species and age classes across the landscape.[108, 109] Therefore, ecosystem management supports the development of new forest management approaches that maintain these critical ecological processes.

The emulation of natural disturbance has been proposed as a way to conserve the majority of species without the need for exhaustive species-specific guidelines. Such emulation would be used as a coarse filter to maintain the range of forest environments that would be produced by natural disturbance.[5, 51, 52, 53, 55, 110, 111, 112, 113] On the other hand, fine filters will also need to be used when the adequate habitat for particular species cannot be provided for in a coarse-filter approach (see Box 2).

Using coarse and fine filters to protect habitat for the full range of boreal species will require the adoption of a broader range of silvicultural strategies. The Ontario Ministry of Natural Resources (OMNR) moved towards recommending alternative silvicultural procedures with the publication of the "*Silviculture Guide to Managing Spruce, Fir, Birch, and Aspen Mixedwoods in Ontario's Boreal Forest*".[211] Silvicultural systems described in the guide include seed tree, shelterwood and selection systems as well as enhanced overstory retention to meet biodiversity objectives.

Additionally, Ontario's "*Forest Management Guide for Natural Disturbance Pattern Emulation (NDPE Guide)*[55] requires residual-stand structures to be produced using modified clearcut systems.

5.1 Key considerations for alternative forestry practices

Silvicultural activities affect habitat by removing, modifying, conserving or enhancing the habitat attributes described in Section 4. Removal, modification and conservation of habitat features can occur during harvest, site preparation (e.g., scarification, prescribed burning) and subsequent stand tending (thinning, understory planting, etc). Limiting habitat removal and deleterious habitat modifications will require that specific consideration be given to habitat values during block layout, tree marking and post-harvest site preparation.

Habitat enhancement, however, will be a later consequence of both the initial choice of silvicultural system and the nature of subsequent stand-tending activities. Because habitat attributes, such as snags, tend to be created and evolve over long periods of time, there is much less assurance that habitat enhancement efforts will be successful. Therefore, adaptive management in which the theoretical benefits of alternative silvicultural practices are monitored must be used to maximize the probability of successful habitat restoration.

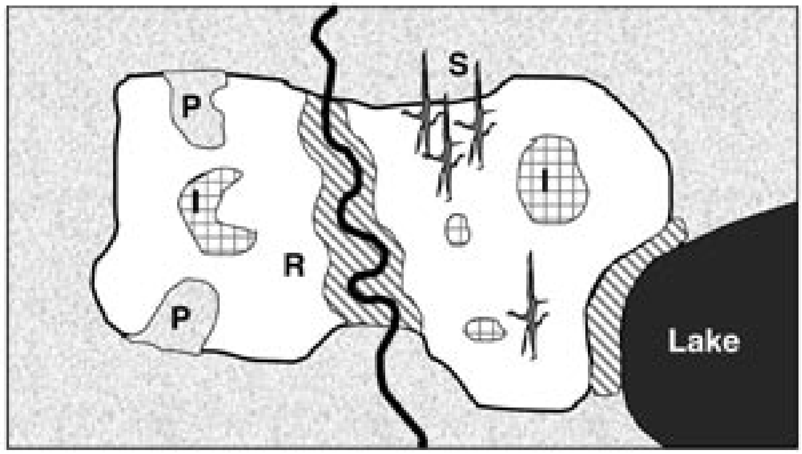
In this section, we match alternative silvicultural approaches with the habitat attributes that they can potentially conserve, retain or enhance. Our descriptions of silvicultural systems follow a gradient of progressively greater habitat retention, from modified clearcuts to selection and underplanting systems that maximize habitat retention.

5.2 Modified clearcuts

Seed-tree systems maintain some habitat elements as a byproduct of a timber-focused regeneration strategy, which retains scattered trees of wind-dispersed species[21] to aid with regeneration in harvested stands. These seed trees have some minor value as residual habitat. However, the retention of larger groups of trees under the umbrella terms "retention system" or "variable retention"[115, 116] is arguably the first true habitat-oriented modification to the clearcut system.

Figure 7. Example of a modified clearcut area that might be produced under the emulation guide (after Anon 2001)

Codes: I – forested island; P – Peninsula patch; R – Riparian buffer; S - Snags



Traditional silvicultural systems, such as the seed tree system, are named for the means used to regenerate the forest. By contrast, the primary goal of variable retention is to provide forest structure to satisfy biodiversity conservation objectives.[69, 117, 118] The concept originated from the observation that fires, windthrows and pest outbreaks produce structurally complex residual stands. These typically include isolated, intact residual forest patches or single live trees accompanied by dead or dying trees that rapidly contribute to woody debris on the forest floor.[118] Retention of these biological legacies in clearcuts is thought to help maintain habitat structures, organisms and connections between forest areas that would otherwise be absent for decades after harvesting.[119]

Goals for the amount of forest to be retained in variable retention cuts vary widely. Some researchers suggest retaining 10-70 percent of the stand's original canopy cover for at least one complete rotation.[118] The Government of British Columbia's guidelines require that more than half of the total open area of the cutblock should be within one tree height of the base of a tree or group of trees.[120]

Natural disturbance emulation, as described in Ontario's NDPE Guide, is intended to retain some of the original tree cover, but is essentially a modified clearcut system. The NDPE Guide defines a clearcut as "the harvesting of most of a forest stand or group of stands while retaining 10-36 percent of the original stand or stands in residual patches and an additional minimum average of 25 individual trees or snags per hectare" [55] (see Figure 7). Retention goals are therefore described with respect to both area and specific structural (individual tree and snag) objectives.

Residual habitat in modified clearcuts may fulfill a bridging function between the original forest stand and the future stand that will grow on the site. For example, cavity-nesting birds have been observed to use scattered birch and aspen left in conventional clearcuts in the coast-interior transitional forests in British Columbia.[121]

In Alberta, some birds that are eliminated from slightly modified clearcuts (eight percent retention) are present in reduced numbers in partially cut stands (30-40 percent tree and shrub retention in patches).[122] Birds of old-forest habitats (e.g., red-breasted nuthatch and yellow-rumped warblers) were present in small but increasing numbers from two to 60 years post-harvest.[94] Groups of retained snags and large trees have immediate benefits for woodpeckers.[88] In the sub alpine forests of interior British Columbia, partial harvesting maintained habitat for small mammals similar to that found in uncut forests.[212]

The approach of retaining residual trees and patches is potentially a significant improvement over conventional clearcut systems. The residual patches, peninsula patches and snags retained under this system may provide cover for medium- to large-bodied animals as well as refugia for populations of smaller animals (e.g., red-backed salamanders). As tree cover is re-established in the clearcuts, these residual populations may reoccupy their former habitat.

It should be emphasized, however, that residual patches and buffers only provide sub-optimal habitat for species that prefer continuous old forest. Due to edge effects, a residual patch cannot retain the habitat values it had as part of a mature forest matrix. Furthermore, the residual patch must contain wind-firm, good quality trees if it is to remain standing for any length of time. Personal observation of residual patches in variable retention logging in interior British Columbia suggests that they are often composed of poor quality trees that were not representative of the full range of conditions in the former stand. This is why the National Boreal Standard for the Forest Stewardship Council (an independent voluntary standard for well-managed forests) requires residual retention to be representative of the original stand.[213]

5.3 Natural regeneration and protection of advanced regeneration

The escalating costs of regeneration and a desire to approximate natural processes have stimulated interest in using advanced regeneration for forest renewal. Preserving advanced regeneration (new growth in a stand or forest area) is a low-cost way to secure adequate stocking (density of trees) and to reduce the use of herbicides. This approach can be supplemented by fill planting when desired densities of regenerating species are low.[123, 124]

Systems to protect advanced regeneration have been formalized and are in wide use, especially in black spruce forests. In Ontario, such systems are called Careful Logging Around Advance Growth (CLAAG) or Harvesting with Regeneration Protection (HARP). In Quebec, they are the Coupe avec Protection de la Regeneration et du sols (CPRS) and Coupe avec Protection des Petites Tiges Marchands (CPPTM).

In lowland black spruce stands, these methods involve having a small feller-buncher harvest trees to the right and left of regularly spaced travel corridors. In a CLAAG system, all commercial stems are harvested, and advanced regeneration is targeted for protection. A HARP is a diameter limit cut that leaves trees ≤ 10 cm in diameter at breast height (dbh) behind. Stands in which HARP or CPPTM have been used evolve towards uneven-aged forest stands as they regenerate (see 5.4 below).

It is estimated that 70 percent of the land base in northeastern Ontario has enough advanced regeneration to achieve full, moderate or minimal conifer stocking when using this approach.[123] Because the logging equipment travels along repeatedly used trails, logging to conserve advanced regeneration has the potential to reduce site disturbance and retain understory vegetation in the protection strips.[125, 214]

These methods provide immediate growing stock for timber production and cover for some wildlife species.[124] Residual habitat quality for marten might also be enhanced by retention of >18 square metres per hectare of cull trees and snags.[126] The presence of large advanced regeneration could also provide cover for snowshoe hares.[127] Reduced herbicide use also has potential benefits for vole populations.[128]

Potential, but untested, benefits of HARP, CLAAG and their regional variants also include the retention of lichen cover on older trees and the enhancement of vertical canopy stratification. However, one study found that significant edge effects were created by HARP, which could have a negative impact on some species.[215]

5.4 Uneven-aged systems for lowland black spruce

Uneven-aged silviculture is being applied experimentally in structurally complex peatland black-spruce forests in northeastern Ontario[129]. Operational trials that removed 35 percent, 50 percent and 100 percent of merchantable basal area in stems > 10 cm dbh were compared to second-growth stands that developed after horse-logging in the 1930s.[129] Logging equipment was restricted to repeatedly used trails spaced about 15 metres apart and approximately 4.5 metres in width. Fifth-year results support the conclusion that uneven-aged silviculture is biologically and technically feasible in peatland black spruce.[129]

Uneven-aged silviculture may enhance vertical canopy diversity in lowland black-spruce stands. With the exception of one study,[215] there does not appear to have been any research to evaluate the value of these silvicultural approaches to wildlife when applied to lowland black-spruce stands. However, personal observation suggests that dense black-spruce stands with complex canopies may provide cover and foraging habitat for a variety of birds. Great grey owls are also known to nest primarily in large tamarack trees[130] and black-backed woodpeckers forage preferentially in black spruce and tamarack swamps in Michigan.[131]

John Mitchell

Osprey often require large, old trees.

Although rarely acknowledged, there are silvicultural risks associated with practicing uneven-aged silviculture in lowland black-spruce stands. Low soil temperatures and the consequent buildup of poorly decomposed organic matter could potentially lead to paludification.[132] On paludified sites, soil nutrients become increasingly locked up in organic forms that are unavailable to plants. Another potential hazard on carefully logged sites is a potential increase in ericaceous shrubs (e.g., bog laurel), which may inhibit the growth of black spruce.[133, 134]

5.5 Shelterwood silvicultural systems

Uniform and irregular shelterwood are partial-cut silvicultural systems that retain forest cover for a part of the rotation. During the period in which this cover is retained, they potentially provide more habitat retention options than modified clearcuts and systems designed to protect advanced regeneration [121, 135, 136]. In classic shelterwood systems, the overstory is removed after some time to increase light to the established regeneration. However, the definition has been expanded to include the possibility of retaining part or all of the sheltering residual overstory.

Canopy and super-canopy trees retained in shelterwood cuts as seed trees provide critical habitat for some species. In Wisconsin, for example, 77 percent of osprey and 80 percent of the bald eagle population in Michigan's Superior National Forest build their nests in the crowns of old white pines, which comprise a mere half percent of the forest's largest trees.[137] In central Ontario, shelterwood systems are recommended to promote healthyregeneration of white pine.[138]

Partial harvests in lodgepole pine stands that remove 30 percent of the initial volume in openings of 0.1-0.5 hectares and an additional 30 percent in the form of single trees between these openings can help conserve habitat for small mammals and birds typical of mature forests. However, fine-tuning the post-harvest density in such cuts is necessary because heavy removals can shift species composition toward communities associated with clearcuts.[121]

As its name implies, the uniform shelterwood system generally results in seed trees and regeneration being distributed more or less evenly across the stand. However, such an arrangement may thin out stands too much to provide habitat for interior forest species or for the provision of thermal and security cover.

There is no overriding reason to adhere to an absolutely uniform arrangement of seed trees. Within the limits of the regeneration requirements of the target species, openings could be made larger or smaller. Even where the characteristics of the commercially targeted species demand the retention of a mostly uniform overstory (for example, to protect white pine from weevil attack), trees in part of the stand could be left in groups centred on pre-selected snags or supercanopy trees. Such residual groups would act as buffers around nest sites or as residual cover for moose or deer. Implemented over several harvests, such a system would produce stands that were uneven-aged mosaics of groups of even-aged trees.

Red pine and yellow birch are light-demanding species that would be suited to modified shelterwood or small clearcut systems that leave groups of residual trees. The Ontario MNR has developed plans to manage red pine stands to maintain red pine as the dominant species, and to conserve patches of mature red pine that will develop into old-growth trees. These goals could be accomplished using patch cuts (0.2 hectare) or small clearcuts (2 hectares), which are thought to emulate the stand-level patterns of residual trees left by patchy fires.[119]

Cutting larger gaps will enhance opportunities for the growth of shrubs as well as commercial tree species. Shrub cover can make a site more valuable to bird communities,[65, 66, 139] but creates strong competition for tree seedlings. Managers, therefore, need to try to strike a balance between securing free-to-grow tree regeneration and providing high-quality shrub habitat for birds and other wildlife groups. This is especially the case on moist, nutrient-rich sites that support dense mountain maple or beaked hazelnut in northwest Ontario.[140]

Fortunately, there is considerable scope for varying the way in which the shelterwood system is applied. This variability makes it probably the most adaptable system for simultaneously fulfilling conservation and silvicultural objectives. For instance, uniform shelterwood usually promotes even-aged regeneration across a stand, whereas strip or irregular shelterwood may lead to more uneven-aged conditions from the viewpoint of the whole forest stand.[124] In addition, final removal cuts do not have to be carried out, which may further enhance stand structure.

Shelterwood approaches may also be suitable for regenerating black spruce, white spruce, and birch in boreal mixedwoods.[124] In this case, an irregular shelterwood system has the potential to emulate conditions produced by canopy gaps. A black spruce shelterwood cut should, ideally, incorporate preliminary assessments of advanced regeneration and its subsequent protection. The coniferous component of mixed-wood stands would probably increase under shelterwood systems and cutting to protect advanced regeneration will likely enhance bird habitat for sub-canopy feeding species.

Shelterwood systems should also allow considerable latitude for the conservation of habitat. Irregular shelterwood cuts should allow specific areas to be protected from harvesting. For example, groups of over-mature aspen can be protected because they represent future snags. Supercanopy aspen, white spruce and white pine can be protected to provide perching and nesting sites for birds of prey.

The possibility that excessive shrub growth will stifle seedling growth after shelterwood cuts means that understory light levels must be carefully controlled. The potential advantages of controlling light levels include promoting the regeneration of selected species, release of sub-canopy trees and controlling the growth of shrubs.[142]

Although we are aware of no formal guidelines for controlling understory light in partially cut stands, Lieffers et al[142] summarize a number of potential light control strategies. Shrub competition may be controlled over the long term by establishing dense tree canopies at the beginning of a rotation. By reducing available light to ≤ 10 percent full sunlight, most on-site shrubs can be eliminated. On the other hand, white-spruce seedlings, for maximal growth require light levels of 40-60 percent of full sunlight.

5.6 Single tree and group selection in old stands

Selection cutting affords the opportunity to maximize interior forest conditions while simultaneously allowing the periodic harvest of mature timber. Unlike traditional shelterwood systems in which the final overstory cut leaves a young even-aged stand, selection cuts maintain a continuous cover of all-aged trees by removing some trees in all commercially viable size classes, either singly or in small groups or strips.[143] The amount of timber harvested per cutting cycle is lower in selection cuts than in either clearcuts or shelterwood cuts, but may be offset by more frequent entries into stands at either fixed or variable intervals.

Selection cuts rely on natural regeneration and provide continuous shade.[124] They are therefore most suited to the establishment of shade-tolerant tree species. In boreal mixedwoods, the most shade-tolerant conifers — balsam fir and eastern white cedar — are most abundant in the oldest stands. Old-growth boreal mixed-wood stands in Ontario and Quebec are often complex mixtures of fir, white or black spruce and eastern white cedar, with patches of long-lived paper birch and residual trembling aspen.[7, 107] These stands can persist for 400 years or longer in the absence of fire[144], and could potentially be managed using selection cuts to release advanced regeneration through a moderate increase in light levels.

Group selection is likely to be superior to single-tree selection if managers want to retain aspen, birch, pine and spruce in post-harvest stands. Group selection would increase light levels for these shade-intolerant and mid-tolerant trees, increasing their chances of attaining canopy-tree status.[22, 124, 145] Group selection might therefore be applied to maintain aspen, birch and perhaps white spruce in stands that would otherwise become dominated by fir and cedar.

Although there is a long tradition of applying selection and irregular shelterwood systems to central European forests,[146] selection cutting in Canadian mixed-wood stands faces a number of challenges. First, fir in older mixed-wood stands may be more susceptible to outbreaks of spruce budworm than those growing in younger stands with a hardwood overstory.[147, 148] Second, although group selection has been proposed as an alternative for uneven-aged mixedwoods,[149] there have been very few operational trials of selection silviculture in boreal forest stands.[150] This means there is an element of risk in using selection cuts to encourage old-growth forest structure.

Selection cutting in Canadian boreal mixedwoods has yet to be demonstrated to be economically or ecologically viable. This may largely be due to the fact that until very recently, a silvicultural rationale for its use had not been advanced. Selection cutting should, therefore, be carefully applied on an experimental basis where there is a reasonable chance of stands regenerating naturally (e.g., abundant advanced balsam fir and cedar regeneration). The preferred alternative to employing selection cutting to retain old forest structures is to lengthen rotation ages to ensure that some areas of the forest always exist in this older condition.

5.7 Underplanting and the enhancement of habitat attributes

The harvest methods described so far outline the use of silviculture to *conserve* habitats within post-harvest stands. However, habitat attributes and structural diversity can also be *enhanced* by combining silvicultural activities such as underplanting, partial and selection cutting, and understory protection over an extended period.[27] Such strategies have recently been proposed for aspen-dominated mixedwoods, fir and white spruce stands.[152]

Underplanting white spruce beneath maturing stands of aspen has been successfully tested in Alberta, British Columbia and Ontario. This strategy can enhance the mixed species and vertically stratified stands that support large songbird communities. It also has the silvicultural advantages of reducing the incidence of pests, frost damage and levels of shrub competition.[142, 153, 202]

Site productivity and long-term timber yield may also be greater on mixed species sites[145, 155, 156] when using this combined approach. For example, seedling survival for underplanted spruce can exceed 95 percent, whereas spruce survival in planted clearcuts may be only 10-53 percent.[157, 158, 159, 160, 161]

Older forests have complex structures.

Bruce Petersen

As currently conceived, underplanting aspen with white spruce will create a two-tiered stand structure that can eventually be harvested in two stages.[124] Following overstory removal, a new mixed spruce-aspen stand with a single canopy layer but two age groups will form because of suckering from the aspen roots. This mixed stand can be harvested within 80-100 years, after which a pure aspen stand is expected to regenerate. This would then be underplanted again 25-60 years later.[160] Therefore, an underplanted stand will provide a range of habitat attributes for a variety of species over a 150-200 year period.

Aspen in boreal forests provide so many resources for so many species that they have been described as keystone resources for boreal wildlife.[162] However, where deciduous vegetation is suppressed by herbicides to favour planted conifers (as in most sub-boreal stands in British Columbia), aspen populations may become impoverished over wide areas. This potential loss of aspen has led to a fear that the mixedwoods are becoming "unmixed".[65, 163] Therefore, any silvicultural treatment that conserves mature aspen cover is likely to have positive effects on the retention of biodiversity.

In addition to supporting a diverse community of migratory songbirds, pure and mixed aspen stands are preferred nesting habitat for most woodpeckers. Primary cavity nesters such as the pileated woodpecker pave the way for the rich community of secondary cavity nesters (Figure 6), ensuring that aging aspen will continue to be used by wildlife. Also, by providing the largest dimension CWD in mixedwood and black-spruce stands,[77] aspen provide important winter shelter for the rodents that are the chief prey of the pine marten.

To realize the full ecological advantages of underplanting, some aspen should be allowed to age and die within the stand. These will fulfill cavity tree functions and will fall over between approximately 10 and 30 years after death to become high-quality CWD. This process should pose a minimum of danger to forestry workers because it will likely be complete before the spruce is economically mature.

5.8 Understory scarification and natural seeding

A strategy with similar objectives to underplanting is to rely on natural regeneration after understory scarification in a high seed production year (called a mast year). Good seed years occur every three to five years for mature eastern white pine and every three to seven years for red pine.[203] For this alternative to succeed, mast years must be predicted. This may be done in the year before harvesting by microscopic examination of buds taken from the tops of trees harvested in nearby stands or in the spring of the present year by binocular examination of trees.[164] There has been some success[165] in predicting mast years as a function of weather, but long-term predictions are limited by our ability to predict future weather.[166]

As in underplanting, natural regeneration following scarification during a mast year should establish conifer regeneration in a stand with two canopy layers. Scarification should take place between July and mid-September before the partial removal of the understory. Skidpaths will cover about 30 percent of the area and will need no scarification. Scarification will be done on 35 percent of the remaining area. Harvesting will then take place in the winter, after the majority of seeds have been dispersed.[164]

Uncertainties that affect the reliability of scarification during a mast year include shrub competition, irregular masting behaviour, fluctuations in populations of seed eaters and dispersers, and weather.[164] Nonetheless, it is believed that seedling densities should be high enough in 71 percent of scarification attempts.[164] Although still a rarely applied method, trials during mast years have shown scarification to be effective in establishing the desired natural regeneration.[161, 164, 167, 168, 169]

5.9 Maintaining snags and CWD

Whatever silviculture system is used, snags and CWD must be retained if the conservation of wildlife habitat is a silvicultural objective. Given that a primary goal of forestry is to remove trees, we need to know the quantity of snags and the volume of CWD that are needed to sustain viable wildlife populations. Yet there is little data to form the basis of plans for cavity-tree retention or future CWD supply.[100a] Most guidelines for managing cavity trees, snags and CWD are therefore "rules of thumb" that can only be validated and improved by monitoring and adaptive management.[95, 170]

An understanding of the decay cycle (see Figure 6) will allow foresters to make intelligent decisions about the management of dead wood. Two aspects of the decay cycle must be carefully managed if viable populations of cavity- and CWD-using wildlife are to be sustained. First, the supply of different decay-class trees must be sufficient to sustain minimum population sizes of different animals. Second, current cavity-tree and snag management must provide for the future supply of more advanced decay classes in forests.

Current practices generally support the retention of 1-25 snags per hectare.[2] Actual numbers of snags reported from different forest types range from 0.7 stems per hectare in plains cottonwood forests of Colorado to 440 stems ≤ 10 cm dbh per hectare in Saskatchewan conifer stands[204] and 1,115 stems per hectare in mature Acadian forest.[204] A stand-replacing fire will leave many times this number of standing dead trees per hectare.[2]

The fact that snags are multifunctional for cavity-using species further complicates the selection issue. Cavity-using birds and mammals may use only one cavity per year for nesting, but require many more for feeding, roosting and escape from predators. Additionally, since cavity excavation is part of the nesting ritual for primary cavity nesters, they may excavate additional cavities within the boundaries of their home range. Some secondary cavity nesters, such as house wrens, use up to three cavities per pair each year, each of which is defended. Northern flying squirrels use multiple nesting trees within their range. They and other mammals may shift their nesting sites in response to a buildup of parasites in the cavity.[100]

Responding to these ecological complexities, the biodiversity guidelines for the Fundy Model Forest recommend retaining 10-12 snags per hectare ≥ 20 cm dbh for feeding and 12-15 live or partly dead aspen or beech ≥ 25 cm dbh for nesting.[171] Another approach has been to estimate the numbers of snags needed by adding up the snag requirements of individual species, assuming that secondary cavity-users will be cared for by default [95, 172] (see Tables 2 and 3). However, the figures in Table 3 may be underestimates since they do not account for foraging needs and are based on a model for the northeastern United States. There has been no research into the threshold numbers of snags needed by cavity nesters in Ontario's boreal forest.[95]

The input of CWD to the forest floor depends on the rates at which dead trees fall and decay. The

Table 3. Estimated numbers of snags required per 100 hectares of forest to sustain given percentages of the maximum population for different primary cavity nesters[95]

			Numbers of Snags per 100 hectares				
Species	**Optimum dbh (cm)**	**Optimum Height (m)**	**100% (max pop)**	**80%**	**60%**	**40%**	**20%**
Downy woodpecker	15 - 25	3 - 9	1000	800	600	400	200
Hairy woodpecker	25 - 35	6 - 12	500	400	300	200	100
Pileated woodpecker	45 - 65	12 - 21	60	48	35	25	13
Common flicker	30 - 45	6 - 12	125	100	75	50	25
Black-backed woodpecker	30 - 45	6 - 12	130	105	78	53	26
Three-toed woodpecker	30 - 40	6 - 12	130	105	78	53	26
Yellow-bellied sapsucker	25 - 35	6 - 12	250	200	150	100	50

availability of CWD during succession generally peaks during early and late succession.[173, 174, 175] For 20- to 40-year-old aspen stands in Alberta, snag creation varied from 0.2-8.2 percent of trees per annum, with younger and older trees being the most susceptible to death. Fall-down rates of snags varied from 9-21 percent per year, and were at their minimum in 60-79-year-old stands. Snags tended to remain standing for 10-20 years.[175]

However, in Newfoundland balsam fir and balsam fir-black spruce stands, CWD inputs in post-harvest stands were proportional to numbers of residual paper birch trees.[174] In boreal mixedwoods in western Quebec, large CWD inputs peaked at 100 years, when the post-fire aspen age class began to give way to other species.[176] Spruce budworm outbreaks also influence rates of CWD recruitment.[144, 174]

CWD and snag levels can be partially managed by setting aside living trees that have the potential to become future snags, such as those that are obviously infected by conks or heart rot.[20a] The initial supply of CWD after logging will be determined by the logging methods and how slash is distributed in the post-harvest stand. Slash should be dispersed rather than crushed, burned or windrowed. Other practices to promote CWD retention include using tree-length harvesting (which delimbs and cuts the tree at the stump, rather than full-tree harvesting, which does so at the roadside), retention of unmerchantable tree boles on site, and modifying prescribed burn treatments to retain more slash.[177]

A final consideration arises with respect to timing. Forest management should consider coarse woody debris natural dynamics during succession. For example, consider a simplified conception of natural succession. After a stand-replacing fire, there is an initial pulse of large dead legacy trees. Later, during the canopy transition stage, there is a prolonged pulse of slowly dying large initial cohort trees. Finally, during the gap dynamics stage, there is a constant input of individual or groups of large dying trees.[216] Forest activities could emulate this sequence of coarse woody debris dynamics, especially the pattern during the canopy transition and gap dynamics stages, by either allowing natural dynamics to take their course by varying rotations to include extended rotations [5, 222] or by consciously providing for coarse woody debris input by varying retention levels[69] and varying silviculture systems.[220, 221, 27]

6.0 Economics and logistics of alternative approaches

Alternative silvicultural systems, especially those that rely on natural regeneration, may have economic advantages over clearcut-and-plant approaches. A comparison between alternative silviculture and clearcut-and-plant systems concluded that, with the exception of situations in which herbicides are permitted and full conifer stocking is needed, conventional plantations are never the cheapest approach.[164]

Where applicable, the top economic choices were found to be reliance on advanced regeneration or understory planting.[164] Where advanced regeneration is present but not sufficiently abundant, fill planting and the use of scarifier seeders were the economic methods of choice.[164]

Some quantitative guidelines for the economic implementation of various alternative silviculture methods have been established:[164, 178]

- When logging to protect advanced regeneration, advanced regeneration must be present when partial cuts are undertaken to achieve full stocking (≥26,000 stems/hectare of fir or ≥ 4,000 stems/hectare of white spruce).
- When relying on regeneration from seed in a mast year, at least six square metres of mature conifer basal area should be present. However, less than this will be needed if advanced growth is abundant or moderate stocking is desired.[178]
- For underplanting systems, underplanting should be limited to aspen stands that have 25 percent of full sunlight at planting height for full stocking.

In eastern boreal mixedwood stands, advanced regeneration is usually ubiquitous and aspen crowns transmit relatively little light. Therefore, reliance on advanced regeneration may be the most economical way to regenerate many stands. However, much of the resulting conifer-hardwood canopy may be composed of balsam fir in eastern mixedwood stands where former populations of white spruce *may* have been depleted by historical high-grading.[216] Further increases in the area under balsam fir could result in more severe spruce budworm outbreaks.[217, 218]

Western mixedwoods will generally have insufficient spruce advanced regeneration to meet minimal stocking standards. For these forest types, the most sound silvicultural prescription may be to underplant them with spruce.[164] Although careful logging practices involve added operational costs, their application could reduce the need to invest in site preparation, artificial regeneration and stand tending.[180] One forest management unit (FMU) in northeastern Ontario reported a reduction in its annual silviculture budget from $1.1 million in the mid-1990s to $450,000 in 2000 and credits the reduced cost to advanced-growth protection and the resulting decrease in planting required to regenerate these carefully logged sites.

The potential savings of protecting advanced regeneration in mixedwood stands might also be realized by the use of HARP systems in peatland black spruce. MacDonnell and Groot[129] state that no extra expenditure of time or money would be needed to fully regenerate their study sites to Ontario standards using HARP.

The expected rotation age of 60-80 years for HARP cuts in peatland sites is much shorter than the 120-year rotations associated with clearcut harvesting followed by planting. Shorter rotations may also be achieved at minimal expense by adjusting the diameter limit used in HARP cuts.[181]

Current operational applications of HARP must be subject to careful evaluation. In Ontario, harvesting equipment in operational use are generally larger than those used in the original experiments.[129] Thus, in current operations as much as 50-70% of the harvest area could be in harvest/skid trails, whereas, with the use of the smaller single-grip harvesters in a cut-to-length system (as used experimentally by MacDonnell and Groot 1996), the proportion of the harvest area in harvest/skid trails could be reduced to 15-25%.[216]

7.0 Conclusions and recommendations

7.1 Policy reform

Throughout this report, silvicultural treatments that are not conventional clearcuts have been described as "alternative". However, most of the silvicultural treatments that we have described have been extensively applied in the temperate and mountain forests of Europe for some time[146] — their novelty lies in their application to forestry in Canadian boreal forests.

Workable frameworks for incorporating alternative silviculture into Canadian forestry practices have been developed,[145, 27] but these require policies and field procedures to support their application.

Policies need to be changed to encourage alternatives to clearcutting.

Evan Ferrari

Existing forest management standards and policies in most provinces could actually impede the adoption of alternative silviculture methods. Although the provinces and territories are formally committed to ecosystem-based management, as outlined in Canada's most recent National Forest Strategy (National Forest Strategy Coalition 2003), the required policies to support this approach are not in place.

For example, in Ontario's new *Mixedwood Guide* [211] the use of alternative systems is described, but not encouraged. Silvicultural systems other than clearcutting are generally designated as "not recommended" or "in development." These caveats may have been included in the *Mixedwood Guide* because the guide authors felt that insufficient testing had been done to justify use of these systems.

In the absence of revised silvicultural recommendations, foresters will rely on current standards. However, most standards that are applied to mixedwood stands nationwide were developed under the assumption that these stands should be regenerated as fully stocked, even-aged conifer monocultures, irrespective of the pre-harvest stand composition.[164]

Adding to the problem of outdated standards is the general inadequacy of current systems of prescribing silvicultural treatments and monitoring their results. In Ontario, for example, pre-harvest silvicultural prescriptions (PHSPs) are not consistently done before assigning a silvicultural treatment to a forest stand. Therefore, decisions are not based on the best information.

The inconsistencies between current regulations and emerging best practices have led to calls for current standards to be revised and for new ones that accommodate alternative management approaches to be developed.[22, 124, 145, 182, 183, 184] For this to occur, however, standards and guidelines must catch up to the current state of ecological knowledge.

We recommend that provincial and territorial governments take the following steps to facilitate the use of silvicultural alternatives to clearcutting:

- Accelerate the adoption of alternative silviculture approaches within a well-defined adaptive-management framework.
- Revise information requirements for forest resource inventories[22] and permanent sample plots to include measures of habitat structure.
- Revise harvest modeling approaches to incorporate alternatives to clearcutting and their potential effect on allowable cut.[22, 27]

7.2 Silviculture reform

Silviculture must be viewed as a long-term commitment made for multiple rotations. Temperate and boreal forests do not remain locked in one condition (e.g., even-aged) or developmental stage (e.g., gap dynamics) under natural conditions. Silviculture systems could therefore be used alternately in the same forest stand to manage a variety of stand properties over the long term. All silviculture systems should incorporate specific stand-level habitat as well as timber objectives.

New silviculture approaches in Canada's boreal forest are ready to be applied within an adaptive management framework as well as within a broader system of ecosystem-based management, such as is expressed in the FSC National Boreal Standard.

We believe that some silvicultural innovations can be widely adopted immediately:

- Underplanting aspen or birch with white spruce.
- The use of pre-harvest scarification under canopies of red or white pine to be harvested using seed tree (red pine), group shelterwood (red pine, white spruce or black spruce in mixedwood stands) or uniform shelterwood (white pine).
- Careful logging (HARP / CLAAG) to conserve advanced regeneration and forest structure, providing it is done using smaller machines with a *maximum of 15- 25 percent* of the stand in harvest/skid trails.
- Uniform or strip shelterwood to promote regeneration of white spruce or paper birch from seed.[219]
- Modified clearcutting with significant amounts (10-50 percent) of residual forest retention on extended or variable rotations that allow characteristics of old forests to develop.
- Explicit planning and silvicultural prescriptions for the retention of present and future snags and CWD within all silvicultural systems.

We believe that some silvicultural systems should only be applied experimentally at this time. These approaches could then be applied more broadly if results demonstrate success at achieving silvicultural and wildlife objectives:

- Uneven-aged silviculture in lowland black spruce.
- Single tree and group selection in old boreal forest stands. In absence of demonstrated success, the use of reserves and lengthened rotations continues to be the preferred method for retaining old growth in the forest landscape.

Intentional management of habitat features is key to the success of using alternative silviculture as a conservation tool. At the stand level, such management requires the consistent use of pre-harvest silvicultural prescriptions (PHSPs) to incorporate habitat retention. In particular, future supplies of snags and CWD can be planned for at the pre-harvest stage of forestry operations. We recommend that:

- Pre-harvest silvicultural prescriptions should be expanded in scope and detail to plan the retention of habitat attributes as part of the silvicultural prescription.

7.3 Further research needs

Wildlife biologists have urged a cautious yet flexible approach to forest management. Caution is especially warranted in the northern boreal forest, where less is known about logging-wildlife relationships.[186, 187] Overall, however, we have sufficient knowledge of species-habitat relationships to justify using alternative silvicultural practices under an adaptive-management philosophy.

Researchers should be brought into the adaptive-management cycle to improve our knowledge of the effects of forestry on biotic communities and to refine the adaptive-management framework using the best available science.

We recommend that the following research objectives be pursued under an adaptive-management framework:

- establishing predictive relationships between levels of silvicultural intensity and habitat conservation,
- refining silvicultural and habitat conservation techniques in alternative systems,
- investigating the transferability of alternative silviculture approaches between different parts of the country,
- improving our knowledge of the relationships of individual species with habitat,
- investigating silviculture-habitat relationships in longitudinal studies that study the consequences of forest practices for complete rotations or longer, and
- improving our knowledge of poorly studied taxonomic groups.

Further research on the ecological and economic impacts of alternatives is needed.

Andrea Maenza

In short, although research to date has allowed us to make broad generalizations about species communities and habitat supply, precise descriptions of the relationships between habitat features and individual species remain elusive. There are at least four reasons for this. First, many boreal species thrive in several different habitats. Second, animals occupy habitat across a range of spatial scales, but ecological studies can describe only a few of these. Third, ecological studies seldom measure all variables that are relevant to a species' distribution; for example, moss diversity in boreal mixedwoods is related to very small-scale diversity of organic substrates and micro-topography.[185] Finally, as in the case of migratory songbirds, species populations may be affected by factors outside of the study area, such as loss of overwintering habitat or pollution.

At the community level, there are phyla and orders of organisms for which almost no information exists for Canada's boreal forest. These include lichens, mosses and carabid beetles, groups for which little information exists in Canada, but which are used as reliable environmental indicators in Scandinavian countries.[188, 189, 190, 191]

Some of these research objectives are already being addressed through long-term projects such as the SAFE project at Lake Duparquet, Quebec and the EMEND study in Alberta. The EMEND project, in particular, is providing information on species – habitat interactions for multiple taxonomic groups before and after silvicultural treatments. Notably, this includes an extensive study of forest floor arthropod communities.[210]

As research accumulates, timber-harvest and habitat-suitability models could be used to refine projections of the economic and ecological consequences of different management scenarios. A recent example illustrating the management potential of linked models explored the economic and habitat consequences of a range of management scenarios in the Pacific Northwest.[192]

Operational, technical, and training needs associated with alternative silviculture also should be considered. Technical advances have made alternative silvicultural systems operationally feasible. Such advances include small, versatile logging equipment like cut-to-length systems.[193] A new generation of forwarding and site-preparation equipment is now required to match the small size, agility and flexibility of this new generation of harvesting equipment.[22]

Training and education at the vocational, technical, and professional levels of management are also needed to meet the operational and planning challenges associated with alternative silviculture.[22]

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Appendix A: FSC Certification - Key Issues Addressed

Conventional industrial forestry poses several serious threats to forest ecosystems. Below we look at some of these key threats and how the Forest Stewardship Council (FSC) system addresses them.

KEY THREATS	FSC SOLUTIONS
Loss of habitat: the rate and intensity of logging in Canada's boreal forest is leading to the loss of critical habitat for wildlife. In particular, the declining amount of older and more sensitive forests threatens populations of plants and animals that depend on these habitats for survival. For example, Canada has recently designated woodland caribou, which require old forests, as a threatened species because of habitat loss.	FSC certification requires identification of important habitat areas that are either completely off- limits to logging or are harvested in a way that ensures the survival of species of concern.
Impacts of roads: Logging requires extensive road networks. These fragment large forest areas into smaller and less ecologically valuable habitat blocks. They also allow people to access previously undisturbed areas for hunting and fishing. This can threaten fish and wildlife populations.	FSC certification requires development of strategies for minimizing the extent and impact of road networks.
Regenerating the forest: In many places, the logging that occurs in Canada's forests makes it difficult for a new forest with the same characteristics as the original to redevelop.	FSC certification requires that logging practices be designed to match the desireable characteristics of natural disturbances (e.g. wildfire, windstorms).
Old-growth forests: Many birds, mammals, insects and plants require forests that are old or contain many old trees. Industrial logging has focused on reducing or eliminating these forests.	FSC certification requires that old forests be left standing throughout the forest.
Water quality: Road construction and logging near shorelines can lead to sediment running into lakes and rivers and a general deterioration of water quality. Large areas logged within a watershed can also have a negative impact on water quality and water flows.	FSC certification requires that intact forest areas be left beside lakes and streams.
Economic sustainability and community stability: The current level of industrial logging in many jurisdictions in Canada exceeds the level that can be sustained in the long-term. The industry's focus on logging species like spruce to produce low value-added products like newsprint and wood pulp has resulted in a highly mechanized industry that has been steadily cutting more wood while employing fewer people. A better future for many Canadian logging towns will depend on cutting fewer trees, protecting other economic values in the forest (such as tourism) and using skill, innovation and knowledge to add value to wood products before they leave the community.	FSC certification requires that the harvest level be determined based on long-term ecological sustainability and that mill and forest workers' jobs be protected when investments are made in newer technologies.
Respect for Aboriginal and treaty rights: Canada's boreal forest is home to many Aboriginal peoples and communities. Most forestry operations have been approved in their traditional territories without consideration of their Aboriginal and treaty rights.	FSC certification requires that Aboriginal peoples control management on their lands and territories unless they delegate control with free and informed consent to other agencies. In addition, where traditional knowledge is applied in forest operations, Aboriginal peoples must be compensated for their knowledge by the forest company.

Appendix B: FSC Principles and Criteria

Principle #1: Compliance with Laws and FSC Principles

Forest management shall respect all applicable laws of the country in which they occur, and international treaties and agreements to which the country is a signatory, and comply with all FSC Principles and Criteria.

Principle #2: Tenure and Use Rights and Responsibilities

Long-term tenure and use rights to the land and forest resources shall be clearly defined, documented and legally established.

Principle #3: Indigenous People's Rights

The legal and customary rights of indigenous peoples to own, use and manage their lands, territories, and resources shall be recognized and respected.

Principle #4: Community Relations and Workers' Rights

Forest management operations shall maintain or enhance the long-term social and economic well-being of forest workers and local communities.

Principle # 5: Benefits from the Forest Forest management operations shall encourage the efficient use of the forest's multiple products and services to ensure economic viability and a wide range of environmental and social benefits.

Principle #6: Environmental Impact

Forest management shall conserve biological diversity and its associated values, water resources, soils, and unique and fragile ecosystems and landscapes, and, by so doing, maintain the ecological functions and the integrity of the forest.

Principle #7: Management Plan

A management plan — appropriate to the scale and intensity of the operations — shall be written, implemented, and kept up to date. The long term objectives of management, and the means of achieving them, shall be clearly stated.

Principle #8: Monitoring and Assessment

Monitoring shall be conducted — appropriate to the scale and intensity of forest management — to assess the condition of the forest, yields of forest products, chain of custody, management activities and their social and environmental impacts.

Principle 9: Maintenance of High Conservation Value Forests

Management activities in high conservation value forests shall maintain or enhance the attributes which define such forests. Decisions regarding high conservation value forests shall always be considered in the context of a precautionary approach.

Principle # 10: Plantations

Plantations shall be planned and managed in accordance with Principles and Criteria 1 - 9, and Principle 10 and its Criteria. While plantations can provide an array of social and economic benefits, and can contribute to satisfying the world's needs for forest products, they should complement the management of, reduce pressures on, and promote the restoration and conservation of natural forests.

Appendix C: Other CPAWS Wildlands League Publications

Forestry in Ontario Fact Sheet Series
This series of factsheets has been produced to increase public understanding of the impacts of forestry in Ontario and to present innovative ideas on how these impacts can be mitigated. Topics in the series inlcude shoreline forests, forest certification, preserving biodiversity and habitat, control of public forests, road impacts and monitoring forestry operations.

- Fact Sheet #1: *Shoreline Forests* These ecologically important forests must be protected from the impacts of logging. (November 2001)
- Fact Sheet #2: *Boreal Forest Certification* How ecological certification of logging practices can help protect this vast forest region (August 2001)
- Fact Sheet #3: *Eastern White Pine Forests: Ecology, Threats and Survival* Ontario's provincial tree is under stress from logging (August 2001)
- Fact Sheet #4: *Good Boreal Forestry* How forestry needs to change to protect large, intact, old forests (October 2001)
- Fact Sheet #5: *Control of Public Forests* Can we change from corporate to community control of public forests? (October 2001)
- Fact Sheet #7: *Lessons for Canadians from Swedish Forests* Forestry has had severe impacts on Sweden's forests (August 2002)

Forest Watch
The Wildlands League's Forest Watch program has conducted audits of logging operations in a number of areas as a way of measuring compliance with logging rules and regulation in real-world situations. Our audits, conducted in conjunction with Sierra Legal Defence Fund, have only looked at compliance with existing rules and regulations and did not attempt to measure the ecological sustainability of logging operations. In an era of government downsizing and industry self-regulation, we believe it is important that we keep watch on what is actually happening in our forests.

Cutting Around the Rules: The Algoma Highlands pay the price for lax enforcement of logging rules (April 1998).

Grounds for Concern: An audit of compliance with Ontario Forest Protection Rules - Algonquin Park and the Magpie Forest (January 2000)

Improving Practices, Reducing Harm: Making best practices a practical reality in forest management — Lower Spanish Forest (November 2001)

The Road Less Travelled? A report on the effectiveness of controlling motorized access in remote areas of Ontario (February 2003)

Other publications
Honouring the Promise: Aboriginal Values in Protected Areas in Canada, looks at changing approaches and attitudes toward protected areas from both Aboriginal and western perspectives. This report has been undertaken in cooperation with the National Aboriginal Forestry Association and includes case studies from across Canada as well as a discussion of issues surrounding recognizing Aboriginal rights and values in park creation and management and the changing legal framework for park establishment. (2003)

Remoteness Sells: A report on resource-based tourism in Northwestern Ontario. This report discusses the relationship between the growing remote tourism business and other resource-based industries, particularly foresty. It looks at the policy imbalance between the interests of the tourism industry and forestry planning and suggests ways to ensure that a healthy remote tourism sector can continue to contribute to the diversification of northern economies. (2004)

Restoring Nature's Place: How we can end logging in Algonquin Park, protect jobs and restore the park's ecosystem
This report discusses how timber harvesting and related activities are undermining Algonquin's role as a protected area. It further considers how a logging phase-out could take place in Algonquin in order to restore the park to its proper role of protecting natural systems and species. (2000)

All of these publications can be viewed or ordered from our website at www.wildlandsleague.org/pubs.html or by calling 1-866-310-WILD

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